

Item ID Number 04907 ☐ **Not Scanned**

Author

Corporate Author United States Department of Agriculture, in cooperation

Report/Article Title The Biologic and Economic Assessment of
Pentachlorophenol Inorganic Arsenicals Creosote,
Volume II: Non-Wood Preservatives

Journal/Book Title

Year 1980

Month/Day November 4

Color ☐

Number of Images 0

Description Notes This report is available in the NAL collection, call no.: 1
Ag84Te no.1658.

THE BIOLOGIC AND ECONOMIC
ASSESSMENT OF

PENTACHLOROPHENOL

INORGANIC ARSENICALS

CREOSOTE

VOLUME II: NON-WOOD-PRESERVATIVES



UNITED STATES
DEPARTMENT OF
AGRICULTURE

IN COOPERATION WITH
STATE AGRICULTURAL EXPERIMENT STATIONS
COOPERATIVE EXTENSION SERVICE
OTHER STATE AGENCIES
U.S. ENVIRONMENTAL PROTECTION AGENCY

TECHNICAL BULLETIN
NUMBER 1658-11

ABSTRACT

Pentachlorophenol, inorganic arsenicals, and creosote are the major pesticide chemicals now in use for wood preservation. An estimated 44.5 million pounds of pentachlorophenol (penta), 37.2 million pounds of inorganic arsenicals, and 124 million gallons of creosote and coal tar are used as wood preservatives annually to preserve 327.5 million cu. ft. of wood for many end uses such as cross-ties, lumber, timbers, plywood, crossarms, piling, poles, posts, and other products. Although large volumes of treated wood products are used, these use patterns are such that exposure of humans and animals is very low.

The maximum impact to the United States' economy would result from cancellation of all three RPAR'd preservatives. Based on using substitute material at 1979 prices, this would result in higher costs in excess of 4.5 to \$6.3 billion annually depending on which combination of substitute materials is used. The total costs are higher because the 4.5 to \$6.3 billion accounts for only 86% of the pressure-treated wood products and does not include the 475 million cu. ft. of wood protected by non-pressure processes.

The non-wood-preservative uses of penta, arsenicals, and creosote include herbicide, defoliant, mossicide, biocide, desiccant, growth regulator, fungicide, insecticide, rodenticide, soil sterilant, disinfectant, larvicide, acaricide, arachnicide, miticide, and repellent. The most important of these are cotton desiccant (20 to \$50 million impact), fungicide (\$24 million impact over 6-year period), herbicide, insecticide, and growth regulator (\$5.8 million impact).

The sources of penta found in the environment are not well known, but the penta breakdown mechanism in soil and water is better understood. The persistence of arsenates in the environment is well known. Plants do not accumulate large quantities of arsenic. A vigorous plant is an indication of low arsenic levels. Arsenates form very insoluble compounds in soil and may ultimately absorb to sediment in the aquatic environment. Only limited data are available on the environmental fate of creosote. Naphthalene and its derivatives biodegrade rapidly in soil and water. The higher boiling components decompose at a slower rate.

Based on no-observable-effect level for penta, the safety factors range from 20 to 580,000. Most work situations would result in safety factors of more than 100. The average daily consumption of arsenic by humans in food and water is 80 micrograms. Arsenically treated wood poses minimal exposure because the arsenic is tightly bound to the wood. There are only limited data on the exposure of most other agricultural uses of arsenic. Exposure data are available for application of arsenic as a cotton desiccant. OSHA has set 0.2 mg/cubic meter as the permissible limit for the particulate polycyclic organic material of creosote.

Keywords: Preservatives, arsenicals, pentachlorophenol, creosote, coal tar, neutral oil, wood products, human exposure, animal exposure, economic impact, alternative systems, RPAR, benefit, risk, pressure treatment, non-pressure treatment, brush dip and spray treatment, cross-ties, switch ties, poles, piling, posts, crossarms, lumber, timbers, plywood, wood foundation, millwork, canceled use, exposure analysis, home and farm use, sapstain, particleboard, groundline, herbicide, defoliant, mossicide, biocide, desiccant, growth regulator, fungicide, insecticide, rodenticide, sterilant, disinfectant, larvicide, acaricide, arachnicide, repellent, miticide, pesticide, EPA registration, service life, biologic and economic assessment, toxicity, marine borers, limoria, teredo, decay, termites, annual cost, natural durability.

THE BIOLOGIC AND ECONOMIC
ASSESSMENT OF

PENTACHLOROPHENOL

INORGANIC ARSENICALS

CREOSOTE

VOLUME II: NON-WOOD-PRESERVATIVES

A report of the Pentachlorophenol, Inorganic Arsenicals, Creosote
assessment team to the rebuttable presumption against
registration of Pentachlorophenol, Inorganic Arsenicals, Creosote

Submitted to the Environmental Protection Agency on
November 4, 1980



UNITED STATES
DEPARTMENT OF
AGRICULTURE

IN COOPERATION WITH
STATE AGRICULTURAL EXPERIMENT STATIONS
COOPERATIVE EXTENSION SERVICE
OTHER STATE AGENCIES
U.S. ENVIRONMENTAL PROTECTION AGENCY

TECHNICAL BULLETIN
NUMBER 1658-II

PREFACE

This report is a joint project of the U.S. Department of Agriculture, the State Land-Grant Universities, and the U.S. Environmental Protection Agency, and is the eighth in a series of reports recently prepared by a team of scientists from these organizations in order to provide sound, current scientific information on the benefits of, and exposure to, pentachlorophenol, inorganic arsenicals, and creosote.

The report is a scientific presentation to be used in connection with other data as a portion of the total body of knowledge in a final benefit/risk assessment under the Rebuttable Presumption Against Registration Process in connection with the Federal Insecticide, Fungicide, and Rodenticide Act.

This report is a slightly edited version of the report submitted to the Environmental Protection Agency on November 4, 1980. The editing has been limited in order to maintain the accuracy of the information in the original report.

The use of chemicals to extend the life and usefulness of wood and wood products is extremely important to agriculture and forestry. Durability of wood used in fence posts, animal holding pens, and outbuildings is a major concern to almost every American farmer and rancher. How long the life of wood and wood products can be extended greatly influences our ability to produce adequate supplies of timber and fiber from our forest lands. Pentachlorophenol (penta), which is widely used as a wood preservative, is effective against both bacteria and fungi as well as insects. In addition, its use in preventing sapstain that discolors lumber contributes substantially to the usefulness, acceptability, and beauty of most wood products. Primarily due to their cleanliness and paintability, the arsenical preservative compounds are being used more widely in lumber, timbers, and plywood. This trend is expected to increase with current concerns for aesthetics. Creosote and coal tar products have been used commercially as wood preservatives for over 150 years.

Wood preservatives have made it economically possible to use wood in a wide variety of applications for which it would be unsuitable without treatment. Without wood preservatives, the cost of replacing electric power poles, forest protection facilities, bridges, marine pilings, railroad ties, and other such wood products would make it much more difficult to remain competitive in local and world markets.

The information on agricultural uses, exposure, and economics of penta, arsenicals and creosote is published in two volumes. Volume I covers wood preservative uses for such items as poles, piling, crossties, lumber, timbers, and plywood. Volume II covers non-wood-preservative uses, such as herbicides, growth regulators, desiccants, fungicides, and disinfectants.

Sincere appreciation is extended to the Assessment Team Members and to all others who gave so generously of their time in the development of information and in the preparation of the report. However, in an effort this large the task of revising and editing the contributions and final production of the report was accomplished by a special committee. Members of this committee, which was responsible for the all-encompassing effort, are:

L. R. Gjovik
D. B. Johnson
V. Kozak
E. A. Woolson

W. A. Thompson
J. T. Micklewright
W. A. Dost
D. D. Nicholas

Membership of the Pentachlorophenol, Inorganic Arsenicals and Creosote Assessment Team

- Eldon Behr, Professor, Department of Forestry, Michigan State University, East Lansing, Mich.
- William E. Chappell, Professor of Botany and Plant Physiology, Virginia Polytechnic Institute and State University, Blacksburg, Va.
- William Daniel, Professor of Agronomy, Purdue University, West Lafayette, Ind.
- William Dost, Forest Product Specialist, Cooperative Extension, University of California, Richmond, Calif.
- Donald Eckerman, Economist, Economic Analysis Branch, Environmental Protection Agency, Washington, D.C.
- George Fries, Animal Scientist, USDA, Beltsville, Md.
- Lee R. Gjovik, Research Specialist, Wood Preservation, Forest Service, USDA, Madison, Wis. (Assessment Team Leader, Penta, Arsenicals, and Creosote)
- David Johnson, Staff Research Chemist, Forest Service, USDA, Washington, D.C. (Chairman, Economics/Benefits Subcommittee and Co-Team Leader)
- Dennis Keeney, Chairman, Department of Soil Science, University of Wisconsin, Madison, Wis.
- Van Kozak, Project Specialist-Molecular Biologist, Water Resources Center, University of Wisconsin, Madison, Wis. (Chairman, Penta Subcommittee) Now employed by EPA.
- Michael P. Levi, Leader, Wood Products Section, Extension Forest Resources Department, School of Natural Resources, North Carolina State University, Raleigh, N.C.
- James Micklewright, Forest Products Technologist, Forest Resources Economics Research, Forest Service, USDA, Washington, D.C.
- Charles Miller, Associate Professor of Plant Physiology, Department of Plant Sciences, Texas A&M University, College Station, Tex.
- Darrel Nicholas, Senior Wood Scientist, Institute of Wood Research, Michigan Technological University, Houghton, Mich. Now employed by Mississippi State University.
- William Quinby, Agricultural Economist, Economics, Statistics and Cooperative Service, USDA, Washington, D.C.
- Herman Reitz, Center Director, Agricultural Research Center, University of Florida, Lake Alfred, Fla.
- Virgil Smith, Principal Entomologist, Forest Products Insect Laboratory, Forest Service, USDA, Gulfport, Miss. Now retired.

Warren Thompson, Director, Forest Products Utilization Laboratory, Mississippi State University, State College, Miss. (Chairman, Creosote Subcommittee)

Gary Van Gelder, Professor Veterinary Toxicology, College of Veterinary Medicine, University of Missouri, Columbia, Mo. Now employed by Shell Chemical Co., Houston, Tex.

Edwin Woolson, Research Chemist, SEA, USDA, Beltsville, Md. (Chairman, Inorganic Arsenicals Subcommittee)

Acknowledgments

Appreciation is expressed to the following for their assistance in providing information on the uses of pentachlorophenol, inorganic arsenicals, creosote, production costs, materials treated, economic impacts, comparative efficacy of registered alternatives, the losses associated with inadequate control of the various pests, administrative support, and other related information.

Gary Ballard, Economist, Economic Analysis Branch, Environmental Protection Agency, Washington, D.C.

Elena Boisvert, Economist, Economics Analysis Branch, Environmental Protection Agency, Washington, D.C.

John Brattland, Economist, Economics of Pesticide Regulations, ESCS, USDA, Washington, D.C.

Glenn Carmen, Entomologist and Professor of Entomology, Department of Entomology, University of California, Riverside, Calif. (Calcium Arsenate Slug Control)

Willard Cummings, Plant Pathologist, Plant Sciences Branch, Environmental Protection Agency, Washington, D.C.

Thaddeus Czerkowicz, Microbiologist, Plant Sciences Branch, Environmental Protection Agency, Washington, D.C.

Linda DeLuise, Economist, Economics Analysis Branch, Environmental Protection Agency, Washington, D.C.

Herman Delvo, Project Leader, Economics of Pesticide Regulations, ESCS, USDA, Washington, D.C.

Robert F. Esworthy, Economist, Economic Analysis Branch, Environmental Protection Agency, Washington, D.C.

Gary Fairchild, Economist, Florida Citrus Commission, Gainesville, Fla.

Walter Ferguson, Economist, Economics of Pesticide Regulations, ESCS, USDA, Washington, D.C.

Stanford Fertig, Chief, Pesticide Impact Assessment Staff, SEA, USDA, Beltsville, Md.

Ralph Freund, Economist, Economic Analysis Branch, Environmental Protection Agency, Washington, D.C.

Harold Gaede, Supervisory Economist, Economics Analysis Branch, Environmental Protection Agency, Washington, D.C.

David Graham, Pesticide Use Specialist, Forest Service, USDA, Washington, D.C.

Roger Holtorf, Economist, Economic Analysis Branch, Environmental Protection Agency, Washington, D.C.

Fredrick Honing, Group Leader, Pesticide Use Management and Coordination, Forest Service, USDA, Washington, D.C.

Edmund Jansen, Economist, Economics Analysis Branch, Environmental Protection Agency, Washington, D.C.

George Keitt, Jr., Plant Physiologist, Plant Sciences Branch, Environmental Protection Agency, Washington, D.C.

B. Ted Kuntz, Economist, Economics of Pesticide Regulations, ESCS, USDA, Corvallis, Oreg.

Mark Luttner, Economist, Economics Analysis Branch, Environmental Protection Agency, Washington, D.C.

C. Dudley Mattson, Economist, Economics Analysis Branch, Environmental Protection Agency, Washington, D.C.

Lester Meyers, Economist, Florida Citrus Commission, Gainesville, Fla.

Debra Moe, Economist, Economics Analysis Branch, Environmental Protection Agency, Washington, D.C.

William Moller, Plant Pathologist, University of California, Davis, Calif.

John Neisess, NAPIAP Coordinator Forest Service, USDA, Washington, D.C.

Forrest Nielsen, Research Chemist, Human Nutrition Lab., University of North Dakota, Grand Forks, N.Dak. (Arsenic Essentiality)

Maxcy Nolan, Extension Entomologist, University of Georgia, Athens, Ga. (Calcium Arsenate--Fly control)

Robert O'Brien, Economist, Economics Analysis Branch, Environmental Protection Agency, Washington, D.C.

Paul Ochs, Pesticide Registration Officer, APHIS/Plant Protection Quarantine, USDA, Hyattsville, Md. (Arsenic Trioxide--Rodent Control)

John Osmun, Professor Entomology, Department of Entomology, Purdue University, West Lafayette, Ind. (Sodium Arsenate--Ant Control)

John Parks, Economist, Economics of Pesticide Regulation, ESCS, USDA, Washington, D.C.

Bernard Smale, Plant Physiologist, Plant Sciences Branch, Environmental Protection Agency, Washington, D.C.

Charles Smith, Director, Pesticide Assessment Programs, Office of the Secretary,
USDA, Washington, D.C.

James A. Taylor, Timber Products Specialist, Rural Electrification Administration,
USDA, Washington, D.C.

Robert Torla, Economist, Economics of Pesticide Regulations, ESCS, USDA,
Washington, D.C.

J. Knox Walker, Entomologist, Texas Agricultural Experiment Station, Texas A & M
University, College Station, Tex.

Edward Weiler, Economist, Economics Analysis Branch, Environmental Protection Agency,
Washington, D.C.

Gail Willette, Economist, Economics of Pesticide Regulations, ESCS, USDA,
Washington, D.C.

Herbert S. Wright, Microbiologist, Diagnostic Bacteriology Laboratory, National
Veterinary Services Laboratories, Ames, Iowa (Disinfectant Uses of Creosote
Compounds)

Paul J. Wuest, Professor Plant Pathology, Pennsylvania State University,
University Park, Pa.

Robert Zwick, Associate Professor-Entomology, Mid-Columbia Experiment Station,
Hood River, Oreg. (Lead Arsenate--Cherry Fruit Fly Control)

SPECIAL TERMS, CHEMICALS AND ACRONYMS

ai	active ingredient
aldicarb (Temik [®])	2-methyl-2-(methylthio)propionaldehyde <u>O</u> -(methylcarbamoyl)oxime
aldrin	1,2,3,4,10,10-hexachloro-1,4,4,5,8,8a-mexahydro-, endo, exo-
ametryn (Evik [®] or Gesapax [®])	2-(ethylamino)-4-(isopropylamino)-6-(methylthio)- <u>s</u> -triazine
amitrole	3-amino- <u>s</u> -triazole
AMS	ammonium sulphamate
antu (Krysid [®])	α -naphthylthiourea
AOAC	Association of Official Analytical Chemists
APHIS	Animal and Plant Health Inspection Service
As ₂ O ₃	arsenic trioxide
atrazine	2-chloro-4-(ethylamino)-6-(isopropylamino)- <u>s</u> -triazine
azinphosmethyl (Guthion [®])	<u>O</u> , <u>O</u> -dimethyl <u>S</u> -[(4-oxo-1,2,3-benzotriazin-3(4H)-yl)=methyl] phosphorodithioate)
bendiocarb (Ficam [®])	2,2-dimethyl-1,3-benzodioxol-4-yl methylcarbamate
benefin (Balan [®])	<u>N</u> -butyl- <u>N</u> -ethyl- α,α,α -trifluoro-2,6-dinitro- <i>p</i> -toluidine
bensulide (Betasan [®])	<u>S</u> -(<u>O</u> , <u>O</u> -diisopropyl phosphorodithioate)ester of <u>N</u> -(2-mercaptoethyl)benzenesulfonamide
BHC	benzene hexachloride
Boll's-eye [®]	cacodylic acid and sodium cacodylate
borax	Na ₂ B ₄ O ₇
bromacil (Hyvar X or Hyvar X-L)	5-bromo-3- <u>sec</u> -butyl-6-methyluracil
cacodylic acid (CA or Rad-E-Cate [®])	hydroxydimethylarsine oxide
captan (Orthocide [®])	<u>N</u> -[(trichloromethyl)thio]-4-cyclohexene-1,2-dicarboximide
carbaryl (Sevin [®])	1-naphthyl methylcarbamate

$\text{Ca}_3(\text{AsO}_4)_2$	calcium arsenate
Chip-Cal [®]	tricalcium arsenate
chlordane (Ortho-Klor [®])	1,2,4,5,6,7,8,8-octachloro-3a,4,7,7a-tetrahydro-4,7-methanoindan (60% minimum and not over 40% of related compounds)
chlordecone (Kepone [®])	decachlorooctahydro-1,3,4 metheno-2H-cyclobuta[cd]=pentalen-2-one
chlorfenvinphos (Birlane)	2-chloro-1-(2,4-dichlorophenyl)vinyl diethyl ester
chlorophacinone (Rozol [®])	2-[(p-chlorophenyl)phenylacetyl]-1,3-indandione
chlorpyrifos (Dursban [®])	<u>0</u> , <u>0</u> -diethyl <u>0</u> -(3,5,6-trichloro-2-pyridyl)phospho=rothioate
Ciovap [®] (Ciodrin [®] + Vapona [®])	crotoxyphos (10%) and dichlorvos (2.5%)
Compound 1080 (Fratol [®])	sodium monofluoroacetate
Compound 1081 (Fluorakil 100 [®])	fluoroacetamide
coumafuryl (Fumarin [®])	3-(α -acetonylfurfuryl)-4-hydroxycoumarin
coumaphos (Co-Ral [®])	3-chloro-7-hydroxy-4-methyl,o-ester with <u>0</u> , <u>0</u> -diethyl phosphorothioate
crotoxyphos (Ciodrin [®])	α -methylbenzyl (<u>E</u>)-3-hydroxycrotonate dimethyl phosphate
crufomate (Ruelene [®])	4- <u>tert</u> -butyl-2-chlorophenyl methyl methylphosphor=amidate
CTC	coal tar creosote
Cu-Naph	copper naphthenate
CuO	copper oxide
Cu-8	copper-8-quinolinolate
cythioate (AC-26691)	<u>0</u> , <u>0</u> -dimethyl <u>0</u> -p-sulfamoylphenyl phosphorothioate
dalapon	2,2-dichloropropionic acid
DCPA (Dacthal [®] or Rid)	dimethyl tetrachloroterephthalate
DDT (dicophane or chlorophenothane)	dichlorodiphenyltrichloroethane
DDVP	2,2-dichlorovinyl dimethyl ester phosphoric acid
DEF (De-Green [®])	<u>S</u> , <u>S</u> , <u>S</u> -tributyl phosphorotrithioate

dielddrin	1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-, endo, exo-
diazinon (Basudin [®] or Spectracide [®])	<u>O</u> , <u>O</u> -diethyl <u>O</u> -(2-isopropyl-6-methy-4-pyrimidinyl) phosphorothioate
dicamba (Banvel [®])	3,6-dichloro- <u>O</u> -anisic acid
dichlobenil	benzonitrile, 2,6-dichloro
dichlorvos (Vapona [®])	2,2-dichlorovinyl dimethyl phosphate
dimethoate (Cygon [®])	<u>O</u> , <u>O</u> -demethyl <u>S</u> -(<u>N</u> -methylcarbamoylmethyl) phosphoro=dithioate
dinoseb (Basanite [®])	2- <u>sec</u> -butyl-4,6-dinitrophenol
dioxathion (Delnav [®])	2,3- <u>p</u> -dioxanedithiol- <u>S</u> , <u>S</u> -bis(<u>O</u> , <u>O</u> -diethyl phosphoro=dithioate)
diphacinone (Diphacin [®])	2-(diphenylacetyl)-1,3-indandione
diquat dibromide (Reglone [®])	6,7-dihydrodipyrido[1,2- α :2',1'-c]pyrazinedium dibromide
diuron	3-(3,4-dichlorophenyl)-1,1-dimethylurea
DP	disaster payment
DPR	disaster payment rate
EBDC	ethylene bisdithiocarbamate
endothall (Accelerate [®] , Hydout [®] or Hydrothol [®])	7-oxabicyclo[2,2,1]heptane-2,3-dicarboxylic acid
ethylan (Perthane [®])	1,1-dichloro-2,2-bis(<u>p</u> -ethylphenyl)ethane
FAS	ferrous ammonium sulfate
FCIC	Federal Crop Insurance Corporation
fenac	(2,3,6-trichlorophenyl)acetic acid
fenthion (Baytex [®])	<u>O</u> , <u>O</u> -dimethyl <u>O</u> -[4-(methylthio)- <u>m</u> -tolyl]phosphorothioate
fenuron TCA	1,1-dimethyl-3-phenylurea mono(trichloroacetate)
FIFRA	Federal Insecticide, Fungicide and Rodenticide Act
Folex [®]	tributyl phosphorotrithioite
folpet (Phaltan [®])	N-[(trichloromethyl)thio]phthalimide
FPY	farm payment yield

glyphosate (Roundup [®])	<u>N</u> -(phosphonomethyl)glycine
heptachlor (Drinox TM)	1,4,5,6,7,8,8-heptachloro-3a,4,7,7a-tetrahydro-4,7-methanoindene
H ₃ AsO ₄	arsenic acid
IPM	integrated pest management
karbutilate	<u>m</u> -(3,3-dimethylureido)phenyl <u>tert</u> -butylcarbamate
kg	1,000 kilograms
km	kilometers
lindane (γ BHC or γ HCH)	1,2,3,4,5,6-hexachlorocyclohexane, <u>gamma</u> isomer of not less than 99% purity
linuron	3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea
LPG	liquid petroleum gas
malathion (Cythion [®])	<u>O</u> , <u>O</u> -dimethyl phosphorodithioate ester of diethyl mercaptosuccinate
MCPA	2-methyl-4-chlorophenoxyacetic acid
metham (Vapam TM or SMDC)	sodium methyldithiocarbamate
methiocarb (Mesurol [®])	4-(methylthio)-3,5-xylyl methylcarbamate
methoxychlor (Marlate [®])	1,1,1-trichloro-2,2-bis(p-methoxyphenyl)ethane
methyl bromide	CH ₃ Br
methyl carbamate (Tirpate [®])	2,4-dimethyl-1,3-dithiolane-2-carboxaldehyde <u>O</u> -(methylcarbamoyl)oxime
mirex (Dechlorane [®])	dodecachlorooctahydro-1,3,4-metheno-1H-cyclobuta= <u>[cd]</u> pentalene
monuron	3-(p-chlorophenyl)-1,1-dimethyl urea
naled (Dibrom [®])	1,2-dibromo-2,2-dichloroethyl dimethyl phosphate
Na-penta	sodium pentachlorophenate
NaAsO ₂	sodium arsenite
Na ₂ HAsO ₄	disodium arsenate
OSHA	Occupational Safety and Health Administration
paraquat (Gramoxone [®])	1,1'-dimethyl-4,4'-bipyridinium ion
parathion (Thiophos [®])	<u>O</u> , <u>O</u> -diethyl <u>O</u> -(p-nitrophenyl) phosphorothioate

penta	pentachlorophenol
phorate (Thimet [®])	<u>O</u> , <u>O</u> -diethyl <u>S</u> -[(ethylthio)methyl] phosphorodithioate
picloram (Tordon [®] or Amdon [®])	4-amino-3,5,6-trichloropicolinic acid
pindone (Pival [®])	2-pivalyl-1,3-indandione
piperonyl butoxide (Butacide [®])	α -[2-(2-butoxyethoxy)ethoxy]-4,5-(methylenedioxy)-2-propyltoluene
PMP (Valone [®])	2-isovaleryl-1,3-indandione
ppb	parts per billion
ppm	parts per million
prometon	2,4-bis(isopropylamino)-6-methoxy-5-triazine
pronamide (Kerb [®])	3,5-dichloro- <u>N</u> -(1,1-dimethyl-2-propynyl)benzamide
propoxur (Baygon [®])	<u>O</u> -isopropoxyphenyl methylcarbamate
psi	pounds per square inch
Pyrethrin I (Pyrethrolone)	2,2-dimethyl-3-(2-methylpropenyl)-ester with 4-hydroxy-3-methyl-2-(2,4-pentadienyl)-2-cyclopenten-1-one
Pyrethrin II (Pyrethrolone)	3-carboxy- α ,2,2-trimethyl-1-methyl ester with 4-hydroxy-3-methyl-2-(2,4-pentadienyl)-2-cyclopenten-1-one
Pb ₃ (AsO ₄) ₂	lead arsenate
PbHAsO ₄	lead arsenate (std)
®	Registered trademark
red squill	powdered bulbs or extract of bulbs of <u>Urginea maritima</u> (the most toxic of several glycosides in red squill is scilliroside)
resmethrin (Synthrin [®])	[5-(phenylmethyl)-3-furanyl)methyl 2,2-dimethyl-3-(2-methyl-1-propenyl)cyclopropanecarboxylate
ronnel (Korlan [®])	<u>O</u> , <u>O</u> -dimethyl <u>O</u> -(2,4,5-trichlorophenyl) phosphorothioate
rotenone	1,2,12,12a-tetrahydro-2-isopropenyl-8,9-dimethoxy[1]=benzopyrano[3,4- <u>b</u>]furo[2,3- <u>h</u>] [1]benzopyran-6(6a <u>h</u>)-one
RPAR	Rebuttable Presumption Against Registration
siduron (Tupersan [®])	1-(2-methylcyclohexyl)-3-phenylurea

silvex	2-(2,4,5-trichlorophenoxy)propionic acid
simazine	2-chloro-4,6-bis(ethylamino)-3-triazine
sodium chlorate	NaClO_4
sodium TCA	sodium trichloro-acetic acid
SRS	Statistical Research Service
strychnine	strychnidin-10-one, sulfate
tetrachlorvinphos or stirofos (Rabon [®] or Gardona TM)	2-chloro-1-(2,4,5-trichlorophenyl)vinyl dimethyl phosphate
thidiazuron (Dropp [®] or SN 49537)	<u>N</u> -phenyl- <u>N</u> '-1,2,3,thiadiazol-5-ylurea
thionazin (Zinophos [®])	<u>O</u> , <u>O</u> -diethyl <u>O</u> -pyrazinyl phosphorothioate
toxaphene (Phenacide TM or Phenatox TM)	chlorinated camphene containing 67 to 69% chlorine
TP	target price
trakephon (buminafos)	dibutyl [1-(butylamino)cyclohexyl]phosphonate
trichlorfon (Dipterex [®])	dimethyl (2,2,2-trichloro-1-hydroxyethyl)phosphonate
ULV	ultra low volume
Uniroyal N-252	2,3-dihydro-5,6-dimethyl-1,4-dithiin-1,1,4,4-tetraoxide
WARF	Wisconsin Alumni Research Foundation
warfarin (Kypfarin [®] or Ratox [®])	3-(α -acetylbenzyl)-4-hydroxycoumarin
zinc ion-maneb complex (Dithane [®] M-45 or Manzate [®] 200)	coordination product of zinc ion and manganous ethylenebisdithiocarbamate
Zn-Naph	zinc naphthenate
2,3,6 TBA	2,3,6-trichloro benzoic acid
2,4,5-T (Brush-Rhap [®] or Weedone [®])	(2,4,5-trichlorophenoxy)acetic acid
2,4,-D (Aqua-Kleen [®])	(2,4-dichlorophenoxy)acetic acid

EXECUTIVE SUMMARY

The Environmental Protection Agency (EPA) issued notices of Rebuttable Presumptions Against Registration (RPAR) on creosote, inorganic arsenicals, and pentachlorophenol (penta) on October 18, 1978. The presumptions indicated that these products met or exceeded the risk criteria for various acute and chronic effects (40 CFR 162.11). Approximately 99% of these chemicals are used in protecting wood products against wood-destroying organisms. The balance is used on a wide variety of sites as fungicides, herbicides, insecticides, rodenticides, defoliants, desiccants, growth regulators, sterilants, repellents, and disinfectants. It is estimated that 44.5 million pounds of pentachlorophenol, 42 million pounds of inorganic arsenicals, and 124 million gallons of creosote and coal tar are used annually.

There are no practical chemical alternatives to these RPAR'd materials for structural wood protection where the risk of attack by wood-destroying organisms is high. However, the RPAR'd materials could, in most cases, be used as alternatives for each other. This fact makes the task of evaluating the economic impact of a cancellation difficult. There are no practical alternatives (chemical and non-chemical) to the organic arsenicals as a cotton desiccant, grapefruit growth regulator, or for grape disease control and ant bait uses.

Wood Preservative Uses

The cancellation of all three of the RPAR'd wood preservatives would result in higher costs of 4.5 to \$6.3 billion annually depending on which combination of substitute materials is used. The total costs are higher than this because the 4.5 to \$6.3 billion accounts for only 86% of the pressure-treated wood products and does not include the 475 million cu. ft. of wood protected by non-pressure processes.

Pressure Treatments

The loss of all preservatives on railroad ties would result in average annual cost increases of \$2.1 billion as railroads shifted to concrete ties. Virtually all ties are currently treated with creosote. A cancellation of creosote alone would result in average annual cost increases of \$36.8 million if railroads shifted to penta-treated ties.

The loss of all three preservatives for wood poles used by utilities would result in average annual cost increases of 1.9 to \$2.8 billion depending on the combination of concrete and steel poles that would be substituted.

Because all three materials are used to treat utility poles the cancellation of any one or two of them while retaining the others would result in different impacts. If only creosote were used, average annual costs would increase by \$45.7 million; use of only inorganic arsenicals would result in cost decreases of \$51.8 million; and use of only penta would result in cost increases of \$27.1 million.

The substitution ratio between steel, concrete, and wood piling affects the economic impact. If use of all three preservatives were canceled and concrete piling were substituted for wood piling on a 1.0:1.5 basis, annual average cost would decrease by \$21.5 million. However, if steel pilings were substituted on a 1.0:1.0 basis, costs would increase by \$129.1 million. It is likely that substitution of concrete or steel for treated wood piling would fall somewhere between the

ratios of 1.0:1.5 and 1.0:1.0. Therefore, the actual economic impact would lie between the figures presented.

The loss of all three preservatives on fence posts probably would not result in any significant cost changes if users shifted to steel posts. However, wood posts are often preferred to steel for aesthetic reasons.

The loss of all three wood preservatives for treating lumber, timbers, and plywood would cost from 485 million to \$1,279 million depending on the combination of alternatives used. Alternatives include untreated cedar, redwood, or pine, concrete, steel, and chromated zinc chloride treatments. About 70% of all treated lumber, timbers, and plywood is treated with inorganic arsenicals. Neither creosote nor penta is a satisfactory alternative for these uses.

Non-Pressure Treatment

The cancellation of both penta and creosote for groundline treatment of utility poles would result in increased costs of \$35.3 million annually. Because penta and creosote are equally effective, with equal treatment costs, the loss of either one while retaining the other would not result in significant cost changes.

The loss of penta for sapstain control in lumber would result in a shift to Cu-8 with increased costs of \$280,000 annually. The loss of penta for millwork and plywood would result in a shift to TBTO at an increased cost of \$2.2 million or to Cu-8 at an increased cost of \$4.8 million.

Non-Wood-Preservative Uses

Pentachlorophenol and Pentachlorophenates

The non-wood-preservative uses of penta are: Herbicide, defoliant, mossicide, and biocide.

There are effective chemical alternatives for all of the non-wood-preservative uses of penta. The alternatives accomplish the desired results at equal or lower cost. The impact of canceling penta for these uses would, therefore, be negligible.

Inorganic Arsenicals

The non-wood-preservative uses of arsenicals are: Desiccant, growth regulator (grapefruit), fungicide, insecticide, rodenticide, herbicide, and soil sterilant.

Of the 12 non-wood-preservative uses of arsenicals addressed, there are effective chemical alternatives for some, most of which can be used at equal or slightly higher cost. The four uses for which suitable alternatives are not available are: arsenic acid (cotton desiccant), lead arsenate (growth regulator--grapefruit), sodium arsenate (ant bait), and sodium arsenite (Black Measles--grapes). In addition, alternatives are not as effective as calcium arsenate for Poa annua control in turf, or for slug and snail control in California citrus.

Cancellation of arsenic acid for desiccation of cotton would reduce annual revenues of cotton producers in Texas and Oklahoma by an estimated 20.3 to \$49.9 million. Cancellation of lead arsenate for use on grapefruit would reduce annual revenues of Florida producers by \$5.8 million. If sodium arsenate were canceled for ant bait, householders could shift to other materials that would need to be applied more

frequently, but total costs would be similar; however, if commercial extermination is selected as the control measure, the annual increased cost would be \$42 million. Loss of sodium arsenite for control of Black Measles would result in increased vineyard establishment costs and losses from reduction in grape yields and quality totaling \$13.3 million for producers of fresh market grapes and \$11.0 million for producers of raisin-type grapes over a 6-year period following cancellation.

Creosote, Coal Tar, and Coal-Tar Neutral Oils

The non-preservative uses of creosote, coal tar, and neutral oils are: Disinfectant, larvicide, insecticide, fungicide, herbicide, acaricide, arachnicide, and animal repellent.

Of the 15 non-wood-preservative uses of these chemicals addressed, only 5 are significant from the standpoint of frequency of use and volume of material applied. Drain fly and gypsy moth control (spraying undercarriage of vehicles) are two uses for which registered alternative chemicals are not available.

Fate in the Environment

Penta is ubiquitous in aquatic environments and its sources are unclear. It may result from direct contamination, from degradation of other organic compounds, or from chlorination of water. Penta may be removed from aquatic environments by volatilization, photodegradation, absorption, or biodegradation. Penta's moderate volatility suggests that volatilization may be a route to the atmosphere, but this is highly speculative. Persistence of penta in soil is extremely variable depending on pH, organic content, moisture content, clay mineral composition, free iron content, ion exchange capacity, and the microorganisms present.

Movement, persistence, and fate of arsenate in the environment is well known. Arsenate forms very insoluble compounds in soil and is generally moved only by erosion to aquatic environments where it may be adsorbed to sediment and removed from solution, adsorbed to plants, or ingested and metabolized by aquatic organisms. Under anaerobic conditions arsenate may be reduced to arsenite and metabolized to volatile alkylarsines. Volatilized arsenicals can be adsorbed on dust particles and oxidized to arsenate, methanearsonate, or cacodylate. Plants do not accumulate large quantities of arsenic if they grow well. Oceanic sediments are the ultimate sink for all arsenic.

Data on the environmental fate of the many chemical components of creosote and coal tar are limited. Naphthalene and its derivatives are rapidly biodegraded in both soil and water. The higher-boiling-point compounds such as fluorene, chrysene, anthracene, and pyrenes are much more slowly decomposed than naphthalenes. Available data are much too limited, however, to permit more than speculation on decomposition rates. Some studies have shown that reductions of these compounds in marine environments proceed exponentially with time and that residual amounts fall below the detection limit within 2 to 3 weeks.

Exposure

The no-observable-effect level for fetotoxicity of penta cited by EPA is 5.8 mg/kg/day. This value, divided by actual exposure, gives the safety factor. Varying exposures gave safety factors ranging from 20 to 580,000 for penta and 868 to 25 million for HxCDD. It is expected that the exposure in most work situations will result in safety factors above 100.

Arsenic is present in all water, food and air. Average daily consumption of arsenic by humans in food and water in the United States is 80 micrograms. Exposure to people handling pressure-treated wood is minimal because arsenic is tightly bound and very insoluble. Urine analyses of exposed workers at a fabricating plant were no higher than the general population.

There are no exposure estimates for most non-wood-preserved applications of arsenicals; however, one study of arsenic acid found daily exposure estimates of 13, 9, and 9 micrograms/kg/day for ground rig applications, aerial applications, and ground crews, respectively. Considering the time spent using arsenic in a year, annual exposure estimates were 0.4, 0.2, and 0.8 micrograms/kg/day for these applications. Exposure to bait formulations of sodium arsenate or calcium arsenate would be negligible.

Exposure limits have not been established for chemical components of creosote; however, OSHA has set a permissible limit of 0.2 mg/cubic meter for the particulate polycyclic organic material of this preservative. Cooperative studies by NIOSH and the wood-preserving industry showed that actual exposure levels generally fall well within the OSHA limit.

SUMMARY

In October 1978, the U.S. Environmental Protection Agency (EPA) placed on record a notice of Rebuttable Presumption Against Registration (RPAR) of pesticides containing pentachlorophenol, inorganic arsenic, coal tar, creosote, and coal-tar neutral oil.

This report has been prepared by a team of scientists from the U.S. Department of Agriculture, the State Land-Grant universities, and the Environmental Protection Agency to provide the best data available on exposure to and benefits from the RPAR'd pesticides, as required by the RPAR process.

The RPAR'd Chemicals

Pentachlorophenol (Penta)

Commercial synthesis of penta is accomplished by direct chlorination of phenol. Penta and its salts are highly effective, broad-spectrum biocides. Penta is widely used as a wood preservative, normally carried in a petroleum solvent. A small quantity is converted to the sodium or potassium salt and carried in water solvent. The following compounds and their uses are addressed in this volume:

Pentachlorophenol--herbicide, defoliant, mossicide.
Sodium pentachlorophenate (Na-penta)--herbicide, mossicide, biocide (mushroom houses).

Inorganic Arsenicals

Arsenic is produced as a by-product of the nonferrous smelting industry. It has many uses in forestry, agriculture, and commerce. Restriction of its use would increase waste disposal problems of smelters. The following uses are addressed in this volume:

Arsenic Acid--desiccant (cotton).
Arsenic Trioxide--rodent control.
Calcium Arsenate--annual bluegrass control (turf), slug bait (citrus), fly control (poultry).
Lead Arsenate--growth regulator (grapefruit), cherry fruit fly control (cherries).
Sodium Arsenate--ant bait (buildings).
Sodium Arsenite--Black Measles (grapes), dead-arm (grapes), termites (buildings), semi-sterilant (soils).

Coal Tar, Creosote, and Neutral Oil

Coal tar is a by-product from coking of bituminous coal. Creosote is a complex mixture of organic chemical products of fractional distillation of coal tar. Neutral oil is also a coal tar fraction. Coal tar is used in a number of pesticides and is used, in combination with creosote, as a wood preservative. Creosote is used alone or in combination with coal tar or petroleum as a wood preservative. Creosote and neutral oil are used in a number of other pesticides. The following uses are addressed in this volume:

Coal Tar--insecticide, disinfectant, animal repellent, fungicide, acaricide, arachnicide.
Creosote--animal repellent, larvicide, fungicide, herbicide, insecticide, acaricide, arachnicide.
Neutral Oil--animal repellent, insecticide, acaricide, larvicide, disinfectant.

Triggers

EPA has determined that penta meets or exceeds risk criteria relating to teratogenic and/or fetotoxic effects on mammalian test species; that inorganic arsenic meets or exceeds risk criteria relating to oncogenic, mutagenic, and reproductive or fetotoxic effects on mammalian species; and that creosote, coal tar, and neutral oil meet or exceed risk criteria relating to oncogenicity.

This report of exposure to and benefits from the RPAR'd pesticides is divided into two parts: Wood preservative uses and non-wood-preservative uses. Wood preservative uses are treated in Volume I and non-wood-preservative uses in Volume II. Only the impacts of canceling one or more of the chemicals for use on one or more sites are considered. Analysis of regulatory options short of cancellation is not included.

The RPAR'd chemicals are the basis for an array of registered products used as pesticides or as growth regulators. These uses range from large-volume applications such as growth regulators to minor or nonexistent uses such as rodent control.

Applications

Penta and Its Salts

Herbicide, Defoliant, and Mossicide

Penta is currently used either alone or as an additive to other herbicides for weed control. There are viable substitutes for all herbicidal uses of penta. Penta is rarely used as a defoliant, and satisfactory alternatives are readily available. Penta is used either alone or in combination with other mossicides on roofs, masonry, and lawns. Although alternative chemicals for moss and lichen control are available, the continued use of penta either alone or mixed with other mossicides is important in areas where moss is a severe problem.

Mushroom House Fungicide

Sodium penta is a general hygienic agent used to control diseases in the environment of commercial mushroom beds. Cancellation of Na-penta use would affect one-third of the U.S. mushroom production. Producers would most likely switch to NaCl, a widely used alternative.

Inorganic Arsenicals

Cotton Desiccant

Arsenic acid is used on over 2 million acres of cotton grown in Texas and Oklahoma. It is used to desiccate the leaves prior to harvesting, and is essential to protect the quality of the crop until it can be ginned with a mechanical stripper. Arsenic acid is the only desiccant which will effectively prepare the crop for harvest. Loss in the quality and quantity of both seed and fiber results if harvest is delayed or if complete desiccation of green leaves is not achieved. Severe losses

can occur in 5 days if the moisture content is above 16% in the cotton module. Exposure to applicators is not large when proper safety techniques are employed.

No environmental problems have been associated with the use of arsenic acid when it is applied according to label directions. It will add about 1 ppm As to the surface 6 inches of soil each year. Cotton is used as a clean-till rotation crop with wheat, milo, or sorghum in some areas. Without cotton, the other crops could not be grown, because Johnsongrass could not be controlled.

Rodent Control

The use of arsenic trioxide as a rodenticide is very limited. There are several alternatives that provide better control.

Turf

Calcium arsenate is approved for turf areas and has been sold throughout Canada and the United States over a period of approximately 20 years. It was the standard Poa annua control measure in professional turf areas because of its selective soil treatment behavior.

Slug and Snail Control

Calcium arsenate is effective for the control of slugs and snails when used in bait formulations that include metaldehyde. The bait is significantly cheaper to use than other materials. Exposure is minimal, because it is formulated in pellet or flake form. Slug control on a wide variety of crops may be necessary in rainy years, such as California experienced in 1978.

Fly Control

Calcium arsenate is applied to house fly larva breeding areas under poultry cages, and to manure piles. When calcium arsenate-treated manure is removed from animal operations, it is normally applied to fallow land.

Growth Regulator

The use of lead arsenate as a growth regulator for grapefruit in Florida is one of the two remaining agricultural uses of this pesticide. Current use patterns and legislation restrict application to part of the bearing grapefruit acreage in Florida only. Application rates are moderate, and only one application is used per year. Opportunity for exposure to applicators is minimal. There are no alternatives to the use of lead arsenate for this purpose except other arsenicals. Calcium arsenate would be an acceptable unregistered substitute for lead arsenate and would eliminate lead.

Cherry Fruit Fly Control

Lead arsenate is effective; however, currently it is not being used. Continued registration is desirable in the event resistance to the organic insecticide develops.

Ant Control

Sodium arsenate is used, principally by the householder, hotels, and motels, to achieve control of modest ant infestations. The advantages of sodium arsenate baits

are: 1) Ease of use, 2) limited quantities needed, 3) the toxicant is transported to the colony, and 4) the continuance of control. Formulations packaged in small ready-to-use containers are the safest of such products.

Herbicide and Tree Killer

Sodium arsenite is an effective soil semisterilant for weed and for tree-stump control. Numerous alternatives are available. No benefits over the alternatives seem apparent.

Termite Control

Several long-lasting alternatives are available for control of subterranean termites. However, there are no suitable substitutes for sodium arsenite for certain specialty uses.

Grape Disease Control

Sodium arsenite is effective for control of Dead-Arm, but several alternatives exist. No alternatives to sodium arsenite for Black Measles control are available.

Coal Tar, Creosote, and Neutral Oil

Creosote, coal tar, and coal-tar neutral oil are registered for use for a large number of non-wood-preserving applications, the most common of which are of a herbicidal, fungicidal, insecticidal, and bactericidal nature. Neutral oil products composed principally of neutral oil and coal-tar acids account for most of the volume used.

The varying definitions assigned to the term "neutral oil" are a source of confusion. In presuming against neutral oil the Environmental Protection Agency defined this product as a mixture of hydrocarbons of coal-tar origin from which the tar acids and tar bases have been removed. The Assessment Team was unable to verify that a product conforming to this definition is produced or used in the United States. The coal tar distillate referred to as "neutral oil" and used for the various types of applications referred to above is composed of 75% methylnaphthalenes and 25% coal tar naphtha. It does not contain the high-boiling fractions encompassed in EPA's definition and for which there is some evidence of carcinogenicity in animals. This document addresses only that "neutral oil" product that is currently being produced and used.

Data on the quantities of coal tar, creosote, and neutral oil sold for non-wood-preserving uses are not available. Only vague information on who uses these products, in what quantities, and for what purpose was supplied by the producers and packagers.

Neutral-oil products are sold by the manufacturers to retail outlets, primarily farm and ranch stores, jobbers, veterinary supply houses, and repackaging firms. Only a limited amount (probably less than 5%) is sold directly to user groups. An estimated 65% of the total volume is used as a general disinfectant in animal production and for household and institutional applications. The balance is used as an insecticide and fungicide and for such site-specific applications as gypsy moth control, screwworm and ringworm wounds in animals, and animal dips for non-food animals. Some neutral-oil products are apparently still used for control of parasites in poultry houses, notwithstanding the fact that this use was canceled in 1972.

Specific examples of the application of coal tar products for many of the uses for which they are registered were not uncovered by the Assessment Team. Exceptions are their uses as disinfectant in animal production, which was viewed by experts in the field as an important part of the total animal health program, and for control of the gypsy moth. The latter use constitutes a USDA regulatory treatment that is considered to be essential because of the economic importance of the gypsy moth and the fact that no alternative chemicals are registered for this use.

Data on efficacy of neutral-oil products for all except disinfectant uses are lacking.

Dermal and inhalation exposure at the point of manufacture of neutral-oil-containing formulations is judged to be small. Approximately two-thirds of the formulating companies have apparently met OSHA standards with regard to employee safety. A relatively small number of employees (estimated at less than 1,000) are directly involved in the manufacture and packaging of these products, and duration of exposure for those most directly involved in these activities is generally less than 100 hours per year.

The population of users is estimated at 100,000 to 500,000. Exposure varies with method of application but is judged to be quite small on an annual basis because of infrequency of use and the low concentration (about 0.5%) of neutral oil in ready-to-use solutions.

The environmental fate of only those constituents of neutral oil that are discussed above is addressed in this document.

Among coal-tar chemicals used as pesticides, the naphthalenes are unquestionably among those that are most subject to biological oxidation. Evidence amassed by numerous studies shows with a high degree of certainty that these chemicals are rapidly decomposed in both aquatic and terrestrial environments by several species of microorganisms. No evidence was uncovered by the Assessment Team that naphthalene compounds accumulate in plants. The fate of these compounds in the air is unknown, but it is assumed that they are broken down in part by photochemical oxidation and, upon settling to earth, by soil bacteria.

VOLUME II—NON-WOOD-PRESERVATIVE USES

CHAPTER 1: PENTACHLOROPHENOL AND PENTACHLOROPHENATES

	<u>Page</u>
Herbicide, Defoliant, and Mossicide	2
Methods of Application.	3
Use Patterns and Efficacy	4
Rights-of-Way	4
Tank Farms and Industrial Areas	5
Parking Lots.	5
Home Use.	5
Use Patterns as Indicated by Major Manufacturers.	5
Exposure Analysis	6
Fate in the Environment	6
Alternatives.	6
Na-Penta as a Mushroom House Biocide.	8
Methods of Application.	9
Spray Application	9
Dip Application	9
Use Patterns and Efficacy	9
Exposure Analysis	10
Fate in the Environment	10
Alternatives.	10
Summary of Biological Analysis—Pentachlorophenol and Pentachlorophenates	11
Herbicide, Defoliant, and Mossicide	11
Mushroom House Biocide.	11
Economic Impact Analysis of Canceling Pentachlorophenol and Pentachlorophenate Uses	12
Herbicide, Defoliant, and Mossicide	12
Introduction	12
Herbicide Uses of Penta	12
Defoliant Use of Penta	12
Mossicide Use of Penta on Lawns	12
Other Mossicide Uses of Penta	13
Summary of Economic Impact Analysis of Canceling Pentachlorophenol	13
Pentachlorophenol—Herbicide Uses	13
Pentachlorophenol—Defoliant Uses	14
Pentachlorophenol—Mossicide Uses	15
Na-Penta as a Mushroom House Biocide.	16
Introduction	16
Impacts of Cancellation	16
Limitations of the Analysis	16
Summary	16
Summary of Economic Impact Analysis of Canceling Pentachlorophenate.	17
Pentachlorophenate—Mushroom House Biocide.	17

CHAPTER 1: PENTACHLOROPHENOL AND PENTACHLOROPHENATES

Herbicide, Defoliant, and Mossicide

Most herbicidal formulations of penta are made by dissolving the parent phenol in oil, methanol, ether, acetone or other solvents. Some herbicidal uses such as in algae control are in the form of the sodium salt. There are no registered herbicidal uses of penta for weed control in food crops either as the sodium salt or the parent phenol. Of the approximately 500 registered labels for herbicides containing penta, a large percentage is for use in industrial areas such as railroads, tank farms, and parking lots. In this report, uses for slime control in paper mills are not included in the total, since these are used primarily to control bacteria and other non-chlorophyll-containing microorganisms.

Most herbicidal formulations containing penta are used for the control of vegetation such as annual grasses and weeds and are not generally used for controlling larger woody plants such as brush sprouts and trees. Only four products have labels for tree control in industrial areas and only 43 out of about 500 products suggest the use of penta for brush control (Table 1).

Table 1.--Number of times that site/pest combinations appear on labels of 500 registered penta products

Pest	Site							Total
	Lawns	Crop	Home and Farm	Roofs and Masonry	Industrial Areas	Rights-of-way	Parking Lots	
Defoliant		1 ^a						1
Moss	50			14				64
Trees					1	1	2	4
Brush			7 ^b		13	6	17	43
Weeds-general ^c			24		130	49	106	309
Annual weeds			68 ^b		142	73	112	395
Perennial weeds			49 ^b		129	75	107	360
Grass-general ^c			28 ^b		110	47	101	286
Annual grass			62 ^b		126	63	96	347
Perennial weeds			61 ^b		125	66	95	347
All vegetation ^c			13 ^b		26	21	30	90
Total	50	1	312	14	802	401	666	2,246

^a Alfalfa grown for seed only.

^b Mostly fence rows.

^c Type not specified.

Because penta products are contact herbicides and usually mixed with phytotoxic oils, a quicker brownout of most vegetation is accomplished even though it might be only temporary for perennial plants. Mixtures of oil and penta are not translocated into the roots and stems of woody or other perennials, and the plants generally recover after a few months. This inadequacy can be overcome by mixing with bromacil or other residual-type herbicides that kill the roots of woody plants.

According to a current survey of formulators, less than 1% (about 400,000 pounds) of the total U.S. penta production is used for herbicide formulations. Although many manufacturers or formulators have not responded to our questionnaire, there is a definite indication that penta is widely used as an herbicide. There are over 500 registered labels for herbicidal use of penta. The results of a questionnaire to manufacturers and formulators of penta for herbicides are shown in Table 2. These figures are a compilation from 179 responses on labeled formulations from a total of over 400 questionnaires. This table shows that most manufacturers favor the continued use of penta as herbicides.

Table 2.--Summary of responses to penta herbicide questionnaire

Question	Yes	No	No Answer
1. Are you currently marketing, formulating, or manufacturing a pesticide under this registration?	99	42	38
2. Would you object to cancellation of this registration?	111	32	36
3. If your answer to question (1) is yes, do you foresee a continued need for this product?	101	30	48
4. Would your firm be willing to help the assessment team by supplying additional information if needed?	83	22	74

Railroad and other applicator groups were contacted in a telephone survey. The general opinion expressed is that little penta is now being used as a herbicide on railroads rights-of-way. One large company indicated that the loss of penta would create a serious problem to its operation, inasmuch as restriction on the use of penta could lead to cancellation of their product registration. Penta is an ingredient in the product as it is currently registered.

Fourteen formulations containing penta for use in moss control on wood roofs and masonry have been registered. Fifty products registered for moss control in lawns were also identified. Although the so-called "moss" that infests roofs is actually a lichen, moss that infests lawns is a true plant of the genus Polytrichum.

Only one defoliant containing penta is registered for use on alfalfa grown for seed. This is for drying the leaves and stems of the plant as a harvest aid.

Methods of Application

Most uses of penta as an herbicide for industrial areas such as railroads, tank farms, and parking lots are applied with power sprayers mounted on railroad tank cars or on trucks. Knapsack sprayers are sometimes used on small areas or for home use. Railroad tank cars are equipped with fixed booms that apply a predetermined volume of spray on a specified area when proceeding at a given speed. Truck-mounted tanks and

sprayers are sometimes equipped with fixed booms to apply penta and mixtures of penta with other herbicides to industrial sites, parking lots, etc. Many trucks and other mobile equipment usually have some type of hand gun on a hose for application to inaccessible areas and to fence rows. Knapsack sprayers with adjustable nozzles are used for small areas around sign posts, building foundations, pavement cracks, and other areas of a similar nature.

For home use, penta may be purchased in ready-to-use forms, such as aerosol cans, or in small containers for use in sprinkling cans or other hand-operated equipment. For moss control, penta is usually sold as the sodium salt and is dissolved in water. It can be applied by brush or knapsack sprayer. Power sprayers could be used on larger surfaces such as brick patios and other masonry areas. Wood-shingled roofs are usually treated with long-handled brushes. Moss control formulations for use on lawns typically contain both fertilizer and a mossicide and are applied in granular form by hand spreader when the lawn is dormant.

For "edging" driveways and killing vegetation around house foundations, penta mixtures are usually applied in oil or emulsified in oil and applied with hand-held equipment.

Defoliants containing penta are applied with low volume (5 to 10 gallons/acre) tractor-mounted booms, but could conceivably be applied by aircraft, although no labeled aerial method of application was found. A telephone survey indicated that penta is rarely used as a defoliant.

Use Patterns and Efficacy

Rights-of-Way

Herbicidal mixtures containing penta are only used on right-of-way areas where total vegetation control is desired, such as on road beds for railroads, electrical substations, bridge abutments, and around road signs. In rights-of-way usage, the addition of bromacil or other soil-sterilant-type compound is essential for full-season weed and grass control. The concentration of penta in mixtures for use on rights-of-way is relatively low--less than 10%--in combination with a phytotoxic oil and a soil sterilant. The function of the penta is to provide a quick "burn" of vegetation. It has little or no lasting herbicidal effect and perennial weeds, grasses, and woody plants require repeated application for adequate control. Penta is non-selective in its action and will knock down all green foliage on contact, but perennial plants will recover in a short time unless longer lasting herbicides are used in conjunction with it. The same killing effect over a long period (1 to 3 months) can be obtained whether or not penta is included. The application rate is 1 gallon concentrate (40% a.i.) to 40,000 square feet or approximately 4 pounds penta per acre.

In rights-of-way where selective removal of woody plants and weeds from grasses or other low growing ground cover is desired, penta is not included in the mixture. It kills the desirable species as well as disrupting normal absorption and translocation of systemic herbicides by killing the leaves too fast. Although many formulations are on the market that contain penta combined with translocated herbicides such as 2,4-D, there is considerable doubt that such mixtures are as effective as when 24-D is used alone. Translocated herbicides work best on healthy, vigorously growing plants. When these herbicides are mixed with penta, the leaves are killed immediately, thus removing the major area of absorption for 2,4-D.

Tank Farms and Industrial Areas

Penta is used in herbicidal mixtures on tank farms and other industrial areas where no vegetation is allowed because of the potential fire hazard. Penta has long been included in such mixtures because of its ability for quick "knock down" of vegetation. Many of the newer soil sterilants prevent most weed and grass growth, and penta is no longer considered absolutely necessary for adequate vegetation control.

The residual herbicidal effectiveness of penta is very low and for that reason its usefulness is questionable except where vegetative growth has not been kept under control by proper management. Longer lasting herbicides are available that will keep all plant growth to a minimum.

Parking Lots

Because penta is a contact herbicide, its use in parking lots is of value only when vegetation has begun to grow in paved or unpaved lots. Its chief disadvantage is that perennial plants are not killed by penta unless other herbicides are combined with it. Thus, it is important to use a suitable soil sterilant along with penta to give longer lasting control of vegetative growth. Soil sterilants must be selected carefully to avoid killing trees or shrubs adjacent to the parking lots due to leaching.

Home Use

With the exception of those penta products formulated for weed control in fence rows, there are very few penta formulations on the market for the homeowner. There are five registered products for controlling weeds in dormant Bermudagrass lawns. The application rate to control weeds in dormant Bermudagrass lawns is 1.6 ounces penta per 1,000 square feet. Other areas of use are: driveways, recreation areas, walkways, and around telephone poles and fence posts. Moss control formulations for use on lawns typically contain both fertilizer and a mossicide, and are applied in granular form by hand spreaders when the lawn is dormant. The application rate of penta to control moss in lawns is 1 pound per acre.

Use Patterns as Indicated by Major Manufacturers

Results of a questionnaire sent to major manufacturers of herbicidal formulations of penta are presented in Table 2. Based on the questionnaires returned, about 400,000 pounds of penta are used in herbicidal formulations annually. This does not represent the total amount used annually, because it was not possible to contact all formulators and applicators.

Defoliants containing penta are rarely used. Adequate alternatives, which are as efficient and safer to use, are available.

The extent of penta usage as a mossicide for roof and masonry applications is unknown. Because only a few alternative products are available for this use, restrictions on the use of penta may result in economic and technical problems among users, particularly where conditions of high humidity and low sunlight favor the growth of roof or masonry moss (lichens).

Usage of penta as a mossicide for lawn application may be substantial in areas of the United States where conditions for moss growth are highly favorable (e.g. the Pacific Northwest). The available data indicate that the use of penta (frequently in combination with other mossicide chemicals) is favored in geographical areas where moss is a serious and persistent lawn pest.

Exposure Analysis

Most herbicidal formulations of penta are applied by hand-held spray equipment, which greatly increases the possibilities of exposure by inhalation or skin contact to the applicator. Remotely controlled fixed nozzles on railroad spray cars offer considerably less exposure potential than hand-held nozzles on power or knapsack sprayers. On larger spray rigs such as railroad spray trains, operators and observers are usually inside an enclosed area and are not likely to be exposed to the spray. Without a complete set of protective clothing, the applicator using hand-held spray guns is in constant danger of dermal and inhalation exposure.

The human exposure from accidental drift can be reduced by using liquid thickeners, but the problem cannot be completely eliminated by this method. The exposure potential of operators spraying penta is in the following declining order: 1) hand gun, power operated; 2) hand gun, knapsack; 3) truck-mounted fixed nozzles. Some degree of dermal and eye exposure may be encountered by individuals involved in filling and mixing operations.

Exposure (and exposure routes) to penta, when applied as a defoliant, would be similar to that encountered during herbicidal application.

Exposure potential when the chemical is applied for moss control on roofs or masonry is highly dependent on the specific application method. Such methods include both spray and brush applications.

Because moss control in lawns involves application of the granular form of penta by hand spreader, human exposure would likely be limited to the dermal route during filling operations.

Fate in the Environment

Penta is broken down in the soil fairly rapidly (Young and Carroll, 1951). Both the parent phenol and the salts are broken down by a number of soil organisms. There is no evidence of penta remaining in the soil for more than one growing season. Loustalot and Ferrer (1950) found that when Na-penta was applied to moist soil at rates as high as 90 pounds per acre it disappeared in 60 days. A more comprehensive treatment of fate of penta and Na-penta in the environment may be found in Volume I, Chapter 3.

Alternatives

There are a number of commercially available herbicides that can be used as alternatives for penta in the applications discussed in this report. These are outlined below.

Railroad ballast and railyards

1. Glyphosate + soil sterilant
2. Paraquat¹ + soil sterilant
3. Sterilants alone

Highways, around structures, and pavement cracks

1. Glyphosate alone
2. Glyphosate + sterilant

Tank farms

1. Glyphosate alone (repeat applications)
2. Glyphosate + soil sterilant
3. Paraquat¹ alone (repeat applications)
4. Paraquat¹ + soil sterilants
5. Sterilants alone

Parking lots

1. Glyphosate alone (repeat applications)
2. Glyphosate + sterilants
3. Paraquat¹ alone (repeat applications)
4. Paraquat¹ + sterilants
5. Sterilants alone

Home use - Fence rows

1. Dicamba + sterilants
2. Picloram + sterilants
3. Glyphosate alone
4. Glyphosate + sterilant
5. Sterilants alone
6. Paraquat¹ alone
7. Paraquat¹ + sterilants

Home use - Driveways and walks

1. Glyphosate alone
2. Paraquat¹ alone + pre-emergence weed killer
3. Paraquat¹ + pre-emergence weed killer

Defoliants

1. Endothall
2. Sodium Chlorate
3. Cacodylic acid¹
4. 5,5,5-tributylphosphorotrithioate
5. Ametryn
6. Paraquat¹
7. Zinc sulfate
8. Zinc chloride

¹ On pre-RPAR list.

Mossicides--Roofs and other wooden structures, masonry and lawns

1. Ferric sulfate
2. Ferrous sulfate heptahydrate
3. Ferrous ammonium sulfate (FAS)
4. Zinc chloride
5. Zinc sulfate

Na-Penta as a Mushroom House Biocide

Commercial mushroom production practices have evolved in response to an ever increasing demand for high-quality mushrooms unscarred by pests and further recognition by farmers of the connection between disease and reduced yields. These developments have resulted in a significant effort to nurture disease-free mushrooms.

Early mushroom cultivation, two centuries ago, made use of natural caves or abandoned mines. Manure was brought in for composting and beds of compost were inoculated with mushroom spawn (seed). Until the late nineteenth century, this practice usually resulted in abandoning the cave after as little as 2 years due to the population pressures of diseases, nematodes, and insects. This problem was greatly aggravated by the use of impure spawn. At the turn of the century, commercial mushroom production in the United States was concentrated in the New York City area, with an expanding supply coming from Pennsylvania in response to the developing market.

Advances in spawn culture techniques led to a method of producing pure spawn more reliably by 1918. By the mid-1920's, scientific research had become institutionalized in the public domain. With the development of a market for processed mushrooms, producers were helped through the depression years. By 1950, development of selective fungicides allowed direct treatment of disease-causing organisms in active mushroom beds. Metal compounds of ethylene bisdithiocarbamate (EBDC) were shown to increase the quality of mushrooms substantially, and marginally increase the yield as compared with no-treatment or use of existing compounds (Yoder, *et al.*, 1950). Zinc-EBDC and benomyl (methyl 1-(butylcarbamoil)-2-benzimidazolecarbamate) are the only effective fungicides registered and labeled for direct mushroom bed application.

In order to minimize the cost per pound of mushrooms, the period of sustained high mushroom yields for each fill of the beds or trays is required. This necessitates the direct application of fungicides to the mushroom beds, sanitizing measures between fills, and minimization of contamination of the bed by insects acting as disease vectors. Insects are also controlled by spraying insecticides in the vicinity of the mushroom houses as often as several times each day during the warm months (Wuest, 1979). This program is targeted primarily at the fly populations, which are attracted to the odors of mushroom houses. The flies are of the small "gnat" type and are both pests and disease vectors.

The primary commercial mushroom in North America, Agaricus bisporus (A. brunnescens), is susceptible to many fungal-induced diseases, but three are of major consequence. (1) Verticillium fungicola (syn. V. malthousei.) is commonly referred to as "dry bubble." The major symptom is spotting and in extreme cases is a small ball of a misshapen mushroom. (2) Mycogone perniciosa causes a disease referred to as "wet bubble" and results in a wet stinking mass. (3) Dactylium dendroides has a mildew effect which digests mushrooms prior to their harvest. Of the three, V. fungicola is the most prevalent fungus attacking mushrooms in the United States.

Trichoderma (green mold or spot) and La France (virus) diseases are most prevalent outside the United States, but both have had significant effects on U.S. crop production. Nematode infestations are another problem in commercial mushroom production. Both disease-causing pathogens and nematodes may be spread by any equipment not sanitized. Certain fly species are mushroom pests in both their larval and adult forms; adult flies may also act as disease vectors.

Na-penta is used as a broad-spectrum hygienic agent to suppress population levels of pest organisms (fungi and insects) on the surfaces of objects in the vicinity of commercial mushroom beds. The compound is applied to the surfaces in a variety of ways, each of which involves dilution in water. It is highly toxic to mushrooms and is applied neither to the growing medium, which is steam pasteurized, nor to the surface of the producing mushroom bed, which is treated with EBDC and/or benomyl. Although the benefits of incorporating Na-penta into hygienic programs have not been objectively measured, it is generally accepted that the material is an effective disinfectant.

Methods of Application

Spray, and dip, are the two basic methods of applying Na-penta in the vicinity of mushroom houses (Wuest, 1979). The only currently registered label specifies dilution to 0.71 pound active ingredient per 50 gallons of water (1,700 ppm Na-penta) for spray and dip applications. The recommended application rate is 50 gallons to 1,000 to 2,000 thousand sq. ft.

Spray Application

Mushroom house exteriors, compost wharfs, lofts, and proximate grounds are sprayed as often as weekly during warm months of the year, but most spray programs call for a 3-week, or even longer, interval between applications. Most of the Na-penta used by mushroom producers is applied by spraying.

Dip Application

Tools are dipped in Na-penta solutions to reduce the transmission of disease-causing organisms from one bed to another or to subsequent mushroom crops.

Use Patterns and Efficacy

The use of Na-penta is not universal among mushroom producers. The exact extent of use is unknown. Based on communications with major mushroom producers (Painter, 1979; and Patton, 1979) and comments by Wuest (1979), it is estimated that one-third of U.S. mushroom production is under a disease control program using Na-penta.

Contacts made with individuals in the mushroom industry or with scientists who have studied mushroom culture have resulted in confirmation of two tenets:

- 1) A facility-wide hygiene program is essential to the viability of the mushroom industry as it is currently known to consumers (i.e., by quality, price, and availability of the product).
- 2) Na-penta is an effective hygienic agent due to a combination of broad-spectrum efficacy, residual efficacy, and other attributes.

However, the industry is in disagreement about whether or not the "best" hygiene program should include Na-penta applications to non-producing surfaces.

A historical perspective helps to explain the current confusion. NaCl, often mentioned as an alternative to Na-penta, was the major chemical agent for mushroom house hygiene until formaldehyde became available. Formaldehyde was eventually displaced by Na-penta when it became available. Recent events have complicated the situation. Tolerance for Na-penta residues in mushrooms was set at zero. This resulted in pressure from many purchasers to eliminate any and all use of Na-penta by producers under contract.

The extent of Na-penta use has diminished partly because of supply problems related to the willingness of manufacturers to continue operating facilities and incurring the costs of keeping labels up to date in a highly regulatory environment. The major domestic manufacturers have discontinued their production of Na-penta. One of the principal distributors, after several months of search, found an alternate U.S. source. Another did not find an alternate source in spite of an intensive search. The only known source of Na-penta for mushroom producers is Mushroom Supply Co. which, after a 6-month period of unavailability due to the loss of its source of supply, has obtained a new label and expects to market approximately 20,000 pounds of its Fungicide "VX" annually. The label does not include among the list of sites any use on empty trays, beds, or even the walls and other surfaces interior to mushroom houses.

There is concern for the risk of product contamination with Na-penta; however, following the current label instructions by not applying Na-penta to the interior of mushroom houses, or to the beds and trays, minimizes the risk from accidental contamination. In place of Na-penta, formaldehyde would be effective for interior surfaces. Unfortunately it is no longer available. NaCl would not be used in place of Na-penta wherever corrosion would be intolerable (e.g. lofts, interior walls and ceilings, and around foundations). NaCl historically has been used on ground and floor surfaces and to antiseptize tools. Wuest (1979) has communicated with some producers on the West Coast who are currently using NaCl and found that they were unaware that Na-penta is again available. A definite preference for Na-penta was expressed by these producers.

Exposure Analysis

Inasmuch as Na-penta is not applied to the mushroom beds, significant consumer exposure is not likely. Of the two methods of application, spray application involves the greatest exposure potential. Inhalation exposure is expected to occur only during spray operations, because the volatility of Na-penta in aqueous solution is very low. The dip methods of treating tools carried from room to room or bed to bed may involve some dermal exposure. The level of such exposure depends on the extent to which personal hygiene and protective clothing are employed.

Fate in the Environment

For a comprehensive treatment of the fate of Na-penta in the environment, see Volume I, Chapter 3.

Alternatives

The only known effective alternative to Na-penta in mushroom production is sodium chloride (NaCl). Castle and Cooke Co., one of the largest mushroom producers, indicated a preference for NaCl and has not used Na-penta for several years (Patton, 1979). They cited cost, convenience, and safety as factors favoring the use of NaCl;

however, it is highly corrosive to both application equipment and metal fasteners used in building construction. Its recommended rate of dilution is 1 pound per gallon of water (Wuest, 1979), which represents approximately 1 pound of salt for every 20 to 40 square feet of surface.

Summary of Biological Analysis—Pentachlorophenol and Pentachlorophenates

Herbicide, Defoliant, and Mossicide

Penta is currently used either alone or as an additive to other herbicides for weed control in rights-of-way, tank farms, parking lots, and home use. Most penta herbicides are applied by various types of spray equipment. Human exposure to penta is highly dependent on the extent to which respirators and protective clothing are utilized and the level of personal hygiene employed by the applicator. Penta's rapid phytotoxicity is its main attribute. Penta has little or no residual activity in the soil and must be mixed with sterilant-type herbicides for long-term weed control. There are acceptable alternatives for all herbicidal uses of penta.

Penta is rarely used as a defoliant, and satisfactory alternatives are readily available. Penta is used either alone or in combination with other mossicides on roofs, masonry, and lawns for the control of moss and lichens. Roof and masonry application is accomplished by spraying or brushing; lawn application generally involves distribution of the granular form by hand spreader. Although alternative chemicals for moss and lichen control are available, the continued use of penta either alone or mixed with other mossicides may be important in areas where moss is a severe problem due to environmental conditions.

Mushroom House Biocide

Na-penta is used to control pest organisms on the surfaces of objects in the vicinity of commercial mushroom beds. It is toxic to mushrooms and is not applied either to the growing medium or to the surface of the producing mushroom bed. Most of the Na-penta used by mushroom producers is applied as an aqueous solution by spraying. In addition to spray application to mushroom house exteriors, compost wharfs, lofts, and proximate grounds, tools are dipped in Na-penta solutions to reduce the transmission of diseases from one bed to another or to subsequent mushroom crops.

Many mushroom producers and mushroom scientists, as well as suppliers, recognize Na-penta as a valuable hygienic agent and express a preference for it over alternatives on many of the possible use sites. Current use of Na-penta is low because many mushroom producers are not aware that Na-penta is again available and because mushroom packers and processors may be reluctant to accept the risk of contamination under the zero tolerance levels. The new label directions may diminish this reluctance. NaCl, the only alternative to Na-penta, is inappropriate for some of the use sites, does not have equally strong residual and broad-spectrum efficacy, and is highly corrosive to metals at the required rates of application. No one has been willing to estimate the efficacy of Na-penta in terms of reduced quality and/or yield when substituting the next best practice. The exact extent of such usage is unknown, but it is estimated that a third of the U.S. mushroom production is under a disease control program using Na-penta.

Of the two methods of Na-penta application, spraying has the greater potential for human exposure. Some dermal exposure to the chemical may occur during dip operations, but the extent of such exposure depends on the extent to which personal hygiene and protective clothing are employed.

The only known effective alternative to Na-penta in mushroom production is sodium chloride. Although it is highly corrosive to both application equipment and metal building fasteners used in building construction, it is likely that cancellation of Na-penta use would result in mushroom producers switching to NaCl in their disease control programs.

Economic Impact Analysis of Canceling Pentachlorophenol and Pentachlorophenate Uses

Herbicide, Defoliant, and Mossicide

Introduction

No major impact is foreseen should penta use as a herbicide, defoliant, or mossicide be canceled. Although penta does have a limited geographic role in control of moss and lichen (especially in the Northwest), the herbicide use is more extensive and may be motivated by economic incentives not explicitly accounted for in this analysis. The herbicide use could be the most important in an aggregate sense of the three.

Herbicide Uses of Penta

For all of the herbicide uses, penta has numerous alternatives of equal or greater efficacy and/or lower cost. Penta at \$12 per gallon (40% a.i.) is combined with oil (\$70 per 100 gallons) at a 1:100 ratio and applied at the rate of 50 to 100 gallons per acre (Chappell, 1979a). The material cost per acre is 41 to \$82.

Glyphosate is equally effective and less hazardous as mentioned above. It is also less expensive to use. Although the chemical cost is \$60 per gallon and requires the same rate of application, dilution is with water rather than oil (Chappell, 1979a). The cost savings are 11 to \$22 per acre. As oil prices climb in 1979 and thereafter, the cost savings will become more accentuated. There remains the possibility that factors not accounted for provide the economic incentives that motivate current use of penta as a herbicide. Either penta or the solvent may be assessed by some users at a surplus or wholesale value below the prices listed above. Oil contaminated with water or dirt has little commercial value and may be used with a little penta for herbicide uses rather than other means of disposal.

Defoliant Use of Penta

Penta has one label for use as a defoliant on alfalfa. It is rarely used as such. In the 1976 Survey of Pesticide Usage, penta was not reported as having been used as an alfalfa defoliant by any of the 1,200 respondents producing alfalfa. Little or no impact is expected should this use be canceled.

Mossicide Use of Penta on Lawns

Penta-containing products are sold for control of lawn moss in western Washington and Oregon. The most likely alternative to the currently popular penta-ferrous ammonium sulfate (FAS) fertilizer combination would be FAS-fertilizer combinations. Equal effectiveness can be achieved with the alternative, but this usually

requires an additional application. In this case labor costs become the major component of increased cost of treatment. Assuming that the user applies the granular mixture with an 18-inch applicator, averaging 1.0 mph, and at a \$5 per hour salary, the labor cost of canceling this use of penta is \$25.50/acre. Estimated lawn acreage in western Washington is 120,000 acres with 3 out of 4 lawns containing some moss. By assuming that western Oregon has 80,000 acres of lawn and that 1/3 of the infested lawn (about 25% of the total lawn area in both States or 50,000 acres) is treated with penta, the total cost of additional labor is \$1,375,000 per year. The extent of use is not known to be this great, however. One major supplier is known to have sold enough penta for 5,000 acres during a recent 3-year period. Total acreage treated with penta is likely to be far less than the 50,000 acres assumed above. Also, the use of \$5 per hour labor charge does not reflect the large number of users who may be applying the material during their leisure hours. This would suggest the use of a lower labor charge were it not for the fact that treated lawns are more likely to be professionally cared for or belong to persons in higher income categories. The cost of materials may also change, but would be insignificant in comparison to the value of additional labor required for the extra application.

Other Mossicide Uses of Penta

The economic benefits of penta used to control mosses and lichens on sites other than lawns are not known due to a lack of data.

Summary of Economic Impact Analysis of Canceling Pentachlorophenol

Pentachlorophenol—Herbicide Uses

- A. USE: Herbicide application to railroad, ballast railyards, farms and industrial areas, parking lots, fence rows, driveways, highways, and walkways.
- B. PLANTS CONTROLLED: Quick "burn" of all vegetation, woody plants recover.
- C. ALTERNATIVES:
- Chemical: Glyphosate, paraquat, sterilants (alone or in combination with other alternatives).
- Non-chemical: Chopping, mowing, tilling where appropriate.
- Comparative efficacy: Alternatives at least as effective as penta are available. Less costly chemical alternatives are available.
- Comparative cost: Glyphosate: 30 to \$50/acre; Penta: 41 to \$82/acre. Mechanical alternatives; 3 to \$500/acre.
- Comments: None.
- D. EXTENT OF USE: Alternatives are preferred to penta. Combined herbicide use is less than 1% of penta production (about 400,000 pounds).

E. ECONOMIC IMPACTS:

User: Not known

Market: Not known

Macroeconomic: Not known

F. SOCIAL/COMMUNITY IMPACTS: Not known

G. LIMITATIONS OF THE ANALYSIS: Some uses of penta as a herbicide may be an alternative to, or a form of, disposal and have zero chemical cost. Recent increases in oil prices will affect the cost of treating with penta much more than the cost of treating with glyphosate.

H. ANALYSTS AND DATE: William E. Chappell, Plant Physiologist
VPI Blacksburg, Va.
William A. Quinby, Ag. Economist
ESCS USDA Wash., D.C.
12/27/79

Pentachlorophenol—Defoliant Uses

A. USE: Alfalfa defoliation for seed harvest.

B. ALTERNATIVES:

Chemical: Endothal; sodium chlorate; cacodylic acid;
5,5,5-tributylphosphorotrithioate; ametryn;
paraquat; zinc sulfate, and zinc chloride.

Non-chemical: None.

Comparative efficacy: Penta has alternatives that are at least as effective.

Comparative costs: Several alternatives are less expensive.

Comments: None.

C. EXTENT OF USE: Known to be rarely used.

D. ECONOMIC IMPACTS:

User: No impact.

Market: No impact.

Consumer: No impact.

Macroeconomics: No impact.

E. SOCIAL/COMMUNITY IMPACTS: No impact.

F. LIMITATIONS OF THE ANALYSIS: None.

G. ANALYSTS AND DATE: William E. Chappell, Plant Physiologist
VPI Blacksburg, Va.
William A. Quinby, Ag. Economist ESCS
USDA Wash., D.C.
12/27/79.

Pentachlorophenol—Mossicide Uses

A. USE: Mossicide.

B. PLANTS CONTROLLED: Lichen and mosses infesting roofs, other wooden structures, masonry, and lawns.

C. ALTERNATIVES:

Chemical: Ferric sulfate, ferrous sulfate heptahydrate, ferrous ammonium sulfate (FAS), zinc chloride, and zinc sulfate.

Non-chemical: None.

Comparative efficacy: Penta is generally considered to be better than the alternatives for controlling moss and lichen.

Comparative costs: FAS costs about the same as FAS with penta (fertilizer combinations), but labor costs are higher.

Comments: Penta formulations with FAS and fertilizer after the best control of moss on lawns. FAS alone requires an extra treatment.

D. EXTENT OF USE: Estimated 50,000 acres treated.

E. ECONOMIC IMPACTS:

User: Not known.

Market: Not known.

Macroeconomic: Minimal.

F. SOCIAL/COMMUNITY IMPACTS: Impacts will be concentrated in the Northwest States where penta use as a mossicide is most heavily favored and where the infestations are most severe.

G. LIMITATIONS OF THE ANALYSIS: Lack of data on extent of use. Lack of data on relative efficacy for sites other than lawns.

H. ANALYSTS AND DATE:

William E. Chappell, Plant Physiologist
VPI Blacksburg, Va.
William A. Quinby, Ag. Economist ESCS
USDA Wash., D.C.
12/27/79

Na-Penta as a Mushroom House Biocide

Introduction

Control of disease in mushroom houses is a primary concern due to the concentration of activities in a relatively small space, the ideal conditions available for disease growth, and the high level of traffic throughout the facility. Because no quantitative estimates of efficacy for this Na-penta use are available, the economic benefits could not be quantified. Even without data relating the use of a particular agent to the suppression of disease outbreaks, it would be premature to disregard any possible benefits.

Impacts of Cancellation

It would be possible to continue to produce mushrooms without the use of Na-penta, but the yield could be reduced and the quality of the crop could be adversely affected. However, despite research on mushroom culture by public institutions for over 50 years, the effects have not been quantified. The value of the mushroom crop in the 1978-79 season was \$360 million. Savings of chemical costs (\$54,000) would be offset by yield or quality losses amounting to only 0.00045% of the \$120 million revenue from affected production (one third of the U.S. production).

Salt (NaCl) is widely used as an alternative to Na-penta. It is considered less effective than Na-penta by the industry, but was generally adopted because either Na-penta was not available or because of concern over the zero tolerance for Na-penta residues in mushrooms. NaCl costs less to apply than Na-penta, but causes corrosion problems in equipment and structures.

A majority of the mushroom crop is now being produced without the hygienic use of Na-penta. Loss of registration would probably have minor economic impact, relative to the value of produce affected.

Limitations of the Analysis

Neither the benefits resulting from the use of Na-penta nor the relative efficacy of Na-penta and its alternative, NaCl, has been quantified. The long-term efficacy of NaCl and the added costs resulting from its corrosivity are not known. The economic risk of a possible product recall that could result as a consequence of Na-penta use in production of a crop with a zero residue tolerance is not included.

Summary

In summary, mushroom producers and mushroom scientists, as well as suppliers, recognize Na-penta as a valuable hygienic agent and express a preference for it over alternatives on many of the possible use sites. Current use of Na-penta is low because many mushroom producers are not aware that Na-penta is again available and because mushroom packers and processors may be reluctant to accept the risk of contamination under the zero tolerance levels. The new label directions may diminish this reluctance. Finally NaCl, the only alternative to Na-penta, is inappropriate

for some of the use sites, does not have equally strong residual and broad-spectrum efficacy, and presents its own environmental problems at the required rates of application. No one has been willing to estimate the efficacy of Na-penta in terms of reduced quality and/or yield when substituting the next best practice.

The economic benefits of Na-penta for mushroom house hygiene are related, in part, to the total value of mushrooms produced. The total impact is unlikely to be more than a small fraction of the total revenue earned by mushroom producers. That revenue has increased from \$62 million in the 1967/68 season to \$360 million in the 1978/79 season.

The strength of preference for Na-penta is explained in its low cost relative to potential benefits. At \$2.70 per pound, the total annual use of 20,000 pounds costs \$54,000. Potential benefits may be in the millions of dollars.

Summary of Economic Impact Analysis of Canceling Pentachlorophenate

Pentachlorophenate—Mushroom House Biocide

- A. USE: Used by mushroom producers, representing one third of the U.S. production capacity, as a broad-spectrum agent for mushroom house hygiene.
- B. SITES:
- Spray application: Mushroom house exteriors, compost wharfs, lofts, and proximate grounds.
- Steam injection: Interiors of vaults or rooms not in production (no longer a labeled use).
- Dip application: Tools.
- C. SPECIES CONTROLLED: Verticillium fungicola, Mycogone perniciosa, and Dactylium dendroides.
- D. ALTERNATIVES: Broad-spectrum disinfectants.
- Chemical alternatives: NaCl (common table salt): non-corroding sites.
- Non-chemical controls: Steam: interiors, not for lofts.
- Comparative efficacy: NaCl is not appropriate for all sites, less effective on appropriate sites.
- Comparative costs: Material costs are not significantly different. NaCl material costs \$0.05/dilute gallon at \$0.05/pound but costs of corrosion are incident to use. Na-penta price is \$2.70/pound or \$0.049/gallon.

E. EXTENT OF USE: Approximately one third of mushroom house capacity or 20,000 pounds of 79% a. i. formulated Na-penta.

F. ECONOMIC IMPACTS: Not known.

User: More corrosion, higher disease pressure, less risk of penta contamination.

Market: Not known.

Consumer: Not known.

Macroeconomics: Not known.

G. SOCIAL/COMMUNITY IMPACTS: Not known.

H. LIMITATIONS OF THE ANALYSIS: Relative efficacy has not been determined.

I. AUTHOR AND DATE: W. A. Quinby, Ag. Economist,
USDA/ESCS Wash., D.C.
1/24/80.

CHAPTER 2: INORGANIC ARSENICALS

	<u>Page</u>
Arsenic Acid.	24
Arsenic Acid—Cotton Desiccation.	24
Methods of Application.	25
Use Patterns and Efficacy	26
Exposure Analysis	26
Aerial Applicator	40
Ground Crew Members	41
Ground Rig Applicator	41
Non-Applicator.	41
Total Exposure.	42
Fate in the Environment	45
Air	45
Water	45
Soil.	45
Alternatives.	46
Insect Control As An Additional Biological Benefit.	48
Summary of Biological Analysis—Arsenic Acid.	48
Economic Impact Analysis of Canceling Arsenic Acid.	49
Arsenic Acid—Cotton Desiccation.	49
Current Use Analysis.	49
Use Impacts	54
Short Season Production System.	54
Alternatives to Arsenic Acid.	55
Use Paterns	55
Assumptions and Procedures for the Economic Analysis.	58
Blacklands.	58
Coastal Regions	59
Texas Plains and Oklahoma	63
Impacts of Arsenic Acid Cancellation.	72
Blacklands.	72
Coastal Regions	75
Texas Plains and Oklahoma	79
Limitations of the Analysis	79
Blacklands.	79
Coastal Regions	79
Texas Plains and Oklahoma	84
Summary of Economic Impact Analysis of Canceling Arsenic Acid.	85
Arsenic Acid—Cotton Desiccant.	85
Arsenic Trioxide.	86
Arsenic Trioxide—Rodent Control.	86
Methods of Application.	87
Use Patterns and Efficacy	87
Exposure Analysis	87
Fate in the Environment	87
Alternatives.	88
Summary of Biological Analysis—Arsenic Trioxide.	88
Economic Impact Analysis of Canceling Arsenic Trioxide.	88
Arsenic Trioxide—Rodent Control.	88
Introduction.	88

	<u>Page</u>
Current Use Analysis.	88
EPA Registrations of Arsenic Trioxide and Alternatives.	88
Arsenic Trioxide Use Patterns	89
Impact Analysis	89
Commensal Rodents	89
Moles and Pocket Gophers.	89
Summary of Economic Impact Analysis of Canceling Arsenic Trioxide.	90
Arsenic Trioxide--Rodent Control.	90
Calcium Arsenate.	92
Calcium Arsenate--Turf.	92
Methods of Application.	93
Use Patterns and Efficacy	93
Exposure Analysis	95
Fate in the Environment	95
Alternatives.	96
Calcium Arsenate--Slug and Snail Bait	96
Methods of Application.	97
Use Patterns and Efficacy	98
Exposure Analysis	98
Fate in the Environment (See Volume I, Chapter 4)	100
Alternatives.	100
Calcium Arsenate--Fly Control	100
Methods of Application.	101
Use Patterns and Efficacy	101
Exposure Analysis	101
Fate in the Environment	102
Alternatives.	102
Summary of Biological Analysis--Calcium Arsenate.	102
Calcium Arsenate--Turf.	102
Calcium Arsenate--Slug and Snail Control.	105
Calcium Arsenate--Fly Control	105
Economic Impact Analysis of Canceling Calcium Arsenate.	105
Calcium Arsenate--Turf.	105
Current Use Analysis.	105
Use of Calcium Arsenate and Alternatives.	107
Economic Impact Analysis.	107
Calcium Arsenate--Slug and Snail Control.	110
Current Use Analysis.	110
Use of Calcium Arsenate and Alternatives.	113
Comparative Performance	114
Economic Impact Analysis.	114
User Impacts.	114
Comparative Costs	115
Market and Consumer Impacts	115
Limitations of the Analysis	115
Calcium Arsenate--Fly Control	115
Summary of Economic Impact Analysis of Canceling Calcium Arsenate.	115
Calcium Arsenate--Turf.	115
Calcium Arsenate--Slug and Snail Control.	116
Calcium Arsenate--Fly Control	118

	<u>Page</u>
Lead Arsenate	119
Lead Arsenate—Growth Regulator	119
Methods of Application.	120
Use Patterns and Efficacy	121
Exposure Analysis	122
Fate in the Environment	124
Alternatives.	125
Lead Arsenate—Cherry Fruit Fly Control	126
Methods of Application.	126
Use Patterns and Efficacy	126
Exposure Analysis	128
Fate in the Environment	128
Alternatives.	128
Summary of Biological Analysis—Lead Arsenate	128
Growth Regulator.	128
Cherry Fruit Fly Control.	129
Economic Impact Analysis of Canceling Lead Arsenate	129
Lead Arsenate—Growth Regulator	129
Current Use Analysis.	129
Use Impacts	151
Current and Alternative Programs.	151
Impact on Production Costs.	151
Impact on Production and Marketing.	151
Changes in Florida Fresh Grapefruit Revenues.	151
Net Producer Level Impact	154
Consumer Impacts.	155
Limitations of the Analysis	156
Lead Arsenate—Cherry Fruit Fly	157
Current Use Analysis.	157
Performance Evaluation of Lead Arsenate and	
Alternatives.	157
Pest Infestation and Damage	157
Comparative Performance Evaluation.	158
Comparative Costs	158
Use Impacts	158
User Impacts.	158
Market Impacts.	160
Consumer Impacts.	160
Social and Community Impacts.	160
Macroeconomic Impacts	160
Limitations of the Analysis	160
Summary of Economic Impact Analysis of Canceling	
Lead Arsenate	160
Lead Arsenate—Growth Regulators.	160
Lead Arsenate—Cherry Fruit Fly	162
Sodium Arsenate	163
Sodium Arsenate—Ant Control.	163
Methods of Application.	163
Use Patterns and Efficacy	163
Exposure Analysis	163
Fate in the Environment (See Volume I, Chapter 4)	164
Alternatives.	164
Summary of Biological Analysis—Sodium Arsenate	
for Ant Control	165

	<u>Page</u>
Economic Impact Analysis of Canceling Sodium Arsenate	165
Sodium Arsenate—Ant Control.	165
Current Use Analysis.	165
Alternatives.	165
Use Impacts	165
Summary of Economic Impact Analysis of Canceling Sodium	
Arsenate for Ant Control.	166
Sodium Arsenite	167
Sodium Arsenite—Non-Selective Herbicide (Soil	
Semi-Sterilization and Tree Killer)	167
Methods of Application.	170
Use Patterns and Efficacy	170
Exposure Analysis	170
Fate in the Environment	170
Alternatives.	170
Sodium Arsenite—Subterranean Termite Control	174
Methods of Application.	174
Use Patterns and Efficacy	174
Exposure Analysis	174
Fate in the Environment (See Volume I, Chapter 4)	175
Alternatives.	175
Sodium Arsenite—Grape Disease Control.	175
Methods of Application.	176
Use Patterns and Efficacy	176
Exposure Analysis	178
Fate in the Environment	179
Alternatives.	180
Summary of Biological Analysis—Sodium Arsenite	180
Non-Selective Herbicide and Tree Killer	180
Subterranean Termite Control.	180
Grape Disease Control	180
Economic Impact Analysis of Canceling Sodium Arsenite	182
Sodium Arsenite—Non-Selective Herbicide and Tree Killer.	182
Sodium Arsenite—Subterranean Termite Control	182
Sodium Arsenite—Grape Disease Control.	182
Introduction.	182
Methodology and Assumptions	183
Current Use Practices	185
Black Measles	186
Phomopsis	186
Estimated Use of Sodium Arsenite and Cost	186
Black Measles	186
Phomopsis	189
Alternatives to Sodium Arsenite	189
Black Measles	189
Phomopsis	189
Use Impacts	189
Black Measles	189
Phomopsis	205
Average Per-Acre User Returns	205
Market and Consumer Impacts	207
Limitations of the Analysis	207
Summary of Economic Impact Analysis of Canceling	
Sodium Arsenite	208

	<u>Page</u>
Sodium Arsenite—Non-Selective Herbicide and Tree Killer.	208
Sodium Arsenite—Subterranean Termite Control	209
Sodium Arsenite—Grape Disease Control.	210

CHAPTER 2: INORGANIC ARSENICALS

Arsenic Acid

Arsenic Acid—Cotton Desiccation

Arsenic acid has been used on over 2,000,000 acres of cotton as a desiccant in Texas and Oklahoma for the past 22 years. It is used as an integral part of an efficient, economical production system utilizing specially bred varieties for shorter growing seasons and harvested with mechanical strippers (Miller, 1974). The gins in the stripper areas have been modified to handle the stripped cotton as a part of the production system. The loss of arsenic acid would have a significant local impact on cotton production in Texas and Oklahoma and further prevent the use of the more economical system by other States.

If seed or bur cotton is excessively wet, it needs to be ginned immediately according to the USDA (1965). Cotton containing less than 8% moisture can be stored indefinitely, whereas cotton with over 14% moisture cannot be stored safely.

The principal sources of moisture in seed or bur cotton are:

1. Harvesting too early or late in the day when dew is present.
2. Rain during storage.
3. Addition of green leaves to the bur cotton.

The first two conditions are easily corrected by timing of harvest while cotton is dry and covering the modules with a cotton tarp. The addition of green leaves to the bur cotton is the principal reason for the use of a desiccant. The stripping operation removes essentially all parts of the plant and only a bare stalk remains in the field. The green leaves become a component of the bur cotton. Approximately 1% green leaf trash in the bur cotton will increase the moisture content of the bur cotton by 1% (Miller, *et al.*, 1968). When there are green leaves left on the plant at harvest time, it is essential to use a desiccant. Desiccants are essential to mechanical harvesting when one or more of the following conditions are encountered: 1) Presence of young, second-growth leaves. 2) Presence of young regrowth leaves. 3) Incomplete defoliation.

Thus, the use of a desiccant in stripper harvesting helps keep the bur cotton moisture below 12% through prevention of added moisture from the leaves. The practice of desiccation and moduling has been examined in other areas such as Tennessee (Mullins and Goddard, 1973).

The desired fiber moisture for ginning was found to be between 6.5 and 9.5% fiber moisture, according to Ward (1963). Overdrying results in lowered quality of the lint.

Cotton desiccants dry green leaves on plants and are used in conjunction with cotton strippers. They are routinely used before mechanical stripping whether or not a defoliant is applied before application of the desiccant. Defoliants will not substitute for desiccants in the preparation of cotton for mechanical stripping except under very isolated, ideal circumstances (Brendel and Miller, 1978). Desiccants are applied under any condition in which green leaves are left prior to stripping because strippers harvest most, if not all, leaves and side branches that are present. The addition of green leaves to seed cotton increases moisture, which creates a condition

whereby the cotton will heat during storage and be lowered in quality while awaiting ginning. If the cotton is too wet, it is essential to dry it before it can be ginned. This would occur when the moisture of the bur cotton keeps the seed above 16% moisture. This condition is encountered in essentially every field without the use of a desiccant. The only exception would be in some years on the High Plains of Texas, where an early freeze results in leaf desiccation.

Cotton is prepared for mechanical harvesting in different ways depending on the variety of cotton, weather conditions, and type of mechanical harvester to be used. In higher yielding, irrigated areas of southern Texas, the general practice is to apply a defoliant such as DEF, Folex, sodium chlorate, or sodium cacodylate, and harvest with revolving spindle-type pickers after the leaves abscise.

In the non-irrigated areas of Texas and Oklahoma, another type of cultural system has evolved. Because maximum yields in dryland cotton are low, mechanical harvesters must be highly efficient. The cotton stripper was developed to meet this need, because pickers leave too much cotton in the field. A stripper operation is a once-over harvest done after desiccation when essentially all the bolls are open. Dried leaves, burs, bracts, side branches, etc., are removed from the stalks, and may be left in the seed cotton. The growers plant storm-resistant types of cotton (Tippit, 1971), which are more adapted to a stripper harvest. Tippit evaluated various varieties of upland cotton adapted for stripper-harvesting. The selection and breeding has progressed for many years so that varieties are planted that are specifically adapted for stripper harvest. Some stripper-type varieties were harvested more efficiently than others (Wilkes, et al., 1959).

The stripped cotton is routinely blown into trailers having wire sides and back. The trailers are towed to the gins and stand up to 5 days in line depending on the backlog. Modern agronomic practices include outside storage of the stripped bur cotton in 10-bale modules. The storage of seed cotton or bur cotton in modules has enabled lengthening of the ginning season and has allowed more cotton to be ginned by fewer gins (Parnell, 1967). Storage in modules may be for periods of 30 days or more before ginning. The longer storage period will, however, allow greater deterioration of lint and seed quality unless the cotton is prepared properly for storage in the module.

Sorenson and Wilkes (1973) reported that field storage of 10-bale modules could be done safely if the modules were covered and moisture percentage was 11% or lower. In a companion study, they reported that when seed temperatures reached 140° F due to moisture, there was an increase in fatty acids and the germination dropped to zero within 21 days of storage.

In certain instances, the storage of cotton in modules has resulted in increased quality. Eickhoff, et al. (1977) reported that storage of cotton in a module system can mean better quality seed and lint. This was the result of examining 4,000 samples in a 2-year study (Cotton Incorporated, 1973).

Methods of Application

Arsenic acid for cotton desiccation is always applied as a spray. About 20 to 30% of the material is applied by aircraft and the rest by ground sprayers. Both self-propelled, high-clearance machines and tractor-mounted sprayers are used in the application by ground. Generally, 3 pints of the product is diluted to a final volume of about 10 gallons of spray solution per acre. Where aircraft are used, 3 pints is applied in a total spray volume of 3 to 5 gallons per acre. Arsenic acid is deliquescent, which allows little drift and no dusting, as in powdery materials.

Use Patterns and Efficacy

Table 3 lists manufacturers, registration numbers, and pertinent information for arsenic acid.

The product is made by reacting trivalent As with nitric acid to yield a 75% H_3AsO_4 . The amounts of nitric and trivalent As are less than 0.10% in the final product.

The 75% aqueous solution has a specific gravity of 1.88 at 60° F and weighs 15.7 pounds per gallon of total material with 11.8 pounds of H_3AsO_4 per gallon. One gallon of the product contains 2,800 g As.

Table 4 shows the use of arsenic acid from 1964 through 1977. The values were supplied by Pennwalt Corporation and reflect the total sales of arsenic acid during the various years. Individual county agricultural agents estimated the total desiccant and defoliant acreage treated in Texas (Table 5). The desiccant acreage includes acreage treated with paraquat. Table 6 is included to enable a comparison between pickers and strippers used in Texas, and contains an estimate of numbers in each county. Figure 1 shows the areas in Texas where cotton is grown desiccated and the varieties grown. Table 7 summarizes Texas cotton production by region.

Table 8 is a listing of cotton acreages in Oklahoma from 1973 through 1979 and is not separated into treated versus non-treated acreage. Arsenic acid is applied to an estimated 100,000 acres, or 20% of the total cotton acreage in Oklahoma (Oswalt, 1978).

The practice of desiccation followed by stripper harvest is increasing. Researchers in other areas are looking at the more economical system developed in Texas and trying the shorter season concept. Johnson, *et al.* (1974), reported that cotton yields increased by 11% in California when planted in narrow rows. Yield increases were even greater for genotypes better adapted to the higher plant populations provided by narrow rows. Their research demonstrated the potential for higher yields, harvested once over, in 180 to 200 days from planting to harvest. Their cotton was harvested with a finger-type stripper harvester. Whiteley, *et al.* (1979), produced just as much cotton on narrow row culture with less production costs than with conventional methods.

Exposure Analysis

Three types of workers are exposed to arsenic acid: Ground crew members who mix the acid for the spray rigs, the aerial applicator, and the ground rig applicator.

Mixing for the ground rig is accomplished directly in the rig's spray tank. Supplemental measuring containers are used where necessary. For aerial application, the concentrate is poured into water, which is pumped into the spray tanks of the aircraft.

The worst exposure situation likely is that of spilling the concentrated 75% product on hands or clothing. The rig or aircraft is always close to the dilution water source at this time so that the individuals would have rinse water handy in case of an accidental spill. The likelihood of a spill out in the field during actual spray application is small and exposure would be to the diluted mixture if it occurred.

Table 3.--Companies with labels registered for arsenic acid use in cotton desiccation^a

EPA Registration Number	Company	Active Ingredient
		Percent
148-674	Thompson-Hayward Chemical Co.	75.0
295-5	Commercial Chemicals	75.0
4581-231	Pennwalt Corp.	75.0
4715-122	Colorado International	75.0
7401-184	Voluntary Purchasing Group	75.0
7401-195	Voluntary Purchasing Group	75.0
7401-200	Voluntary Purchasing Group	75.0
20004-3	Traylor Chemical & Supply	75.0

^a Source: Survey of Manufacturers, 1979.

Table 4.--Amount of arsenic acid sold as cotton desiccant^a

Year	H ₃ AsO ₄ (75% Concentrate)	H ₃ AsO ₄ (100% Basis)
	Gallons	Pounds
1964	983,900	11,610,500
1965	1,093,625	12,904,800
1966	1,015,400	11,981,700
1967	842,400	9,940,320
1968	884,250	10,437,300
1969	742,120	8,757,000
1970	896,825	10,582,500
1973	1,159,800	13,685,640
1974	904,570	10,673,926
1976 ^b	470,000	5,546,000
1977 ^b	700,000	8,260,000
Average	800,000 gallons/year	
Average	2,347,000 acres treated	

^a Data in this table are based on figures supplied by Pennwalt Corp.

^b The supply was limited due to smelter worker strikes in 1977. Much more would have been used if it were available (Miller, 1979).

Table 5.--Texas cotton acreage treated with harvest-aid chemicals in 1977

Counties	Desiccant	Defoliant	Combination	Total
Collingsworth	20,000	5,000		25,000
Donley	4,000			4,000
District 1	24,000	5,000		29,000
Terry	160,000	20,000	20,000	200,000
Yoakum	15,000	30,000		45,000
Scurry	10,000		15,000	25,000
Swisher	3,500			3,500
Lynn	200,000			200,000
Parmer	20,000	4,000		24,000
Lamb	80,000	8,000	2,000	90,000
Lubbock	165,000	15,000	10,000	190,000
Hale	45,000	25,000	8,000	78,000
Hockley	70,000	5,000	6,000	81,000
Gaines	175,000		25,000	200,000
Garza	31,500	400	100	32,000
Dawson	275,000			275,000
Floyd	50,000		40,000	90,000
Cochran	25,000	5,000	2,000	32,000
Crosby	75,000			75,000
Brisco	50,400			50,400
Castro	2,000	2,000		4,000
Bailey	16,000		4,000	20,000
Borden	15,000			15,000
District 2	1,483,400	114,400	132,100	1,729,900
Motley	1,200	500		1,750
Schackelford				
Kings	3,500			3,500
Knox	6,500	1,000		7,500
Jones	85,000			85,000
Kent	1,000		1,000	2,000
Young	360		250	610
Throckmorton	80			80
Wichita	8,000			8,000
Wilbarger	18,000	5,000	2,000	25,000
Fisher	25,000		10,000	35,000
Dickens	10,000	2,500	6,500	19,000
Hall	30,000	1,000	4,000	35,000
Foard			5,000	5,000
Cottle	25,000	5,000		30,000
Hardeman	5,000	3,000	2,000	10,000
Baylor	1,000			1,000
Childress	10,000			10,000
Stonewall	2,000	200		2,200
Haskell	90,000	10,000		100,000
Archer				

Table 5.--Texas cotton acreage treated with harvest-aid chemicals in
1977--continued

Counties	Desiccant	Defoliant	Combination	Total
District 3	321,640	28,250	30,750	380,640
Wise		400		400
Parker				
Rockwall	800			800
Tarrant	3,300			3,300
Montague				
Navarro	35,000	2,500	7,500	45,000
Johnson	22,000			22,000
Kaufman	16,000			16,000
Hunt	27,877			27,877
Jack		150		150
Fannin	5,000			5,000
Grayson	3,000			3,000
Denton	3,500	4,500		8,000
Ellis	80,000			80,000
Collin	20,000			20,000
Cooke	550			550
Dallas	2,000	2,000	1,000	5,000
Clay	1,500			1,500
District 4	220,527	9,550	8,500	238,577
Delta	12,000		2,000	14,000
Lamar	1,500	2,500		4,000
Hopkins				
Henderson		281		281
Van Zandt	5,876			5,876
Red River	950			950
Rains	1,375			1,375
District 5	21,701	2,781	2,000	26,482
Andrews	10,000	2,000		12,000
El Paso				
Culberson				
Howard	75,000		10,000	85,000
Glasscock	10,000	5,000		15,000
Martin	50,000	35,000		85,000
Hudspeth		20,000		20,000
Presidio	60			60
Midland	15,000		4,000	19,000
Upton	9,500			9,500
Reeves	1,500	7,500	1,200	10,200
Reagan				
Pecos		4,000		4,000

Table 5.--Texas cotton acreage treated with harvest-aid chemicals in
1977--continued

Counties	Desiccant	Defoliant	Combination	Total
District 6	171,060	73,500	15,200	259,760
Tom Green	40,000	3,000	2,000	45,000
Sterling				
Taylor	3,500		500	4,000
Runnels	34,000			34,000
Schleicher	4,500	2,000		6,500
Mitchell	28,000	5,000	2,000	35,000
Nolan	25,000			25,000
Irion	200			200
McCulloch	500			500
Coleman	2,000			2,000
Concho	15,000			15,000
Callahan	150			150
Coke	513		170	683
District 7	153,363	10,000	4,670	168,033
Palo Pinto	1,000			1,000
Stephens	220	726		946
Hill	85,000			85,000
McLennan	15,000	5,000		20,000
Eastland				
Erath	160			160
Hamilton	900			900
Brown				
Comanche	300			300
Coryell	1,750			1,750
Bell	17,000		1,000	18,000
Bosque	2,546			2,546
District 8	123,876	5,726	1,000	130,602
Leon	1,000			1,000
Freestone				
Houston	2,800	500	5,100	8,400
District 9	3,800	500	5,100	9,400
Washington	200			200
William	61,500	1,500		63,000
Robertson			15,000	15,000
Travis	7,350	3,000		10,350
Limestone	4,500			4,500
Milam	20,000	5,000	3,000	28,000
Guadalupe	1,697			1,697
Hays	240			240
Lee				
Caldwell	6,648			6,648

Table 5.--Texas cotton acreage treated with harvest-aid chemicals in
1977--continued

Counties	Desiccant	Defoliant	Combination	Total
District 9-- continued				
Falls	16,000	4,000		20,000
Bastrop		1,000		1,000
Brazos			9,000	9,000
Burleson	3,000	14,500	1,000	18,500
District 10	121,135	29,000	28,000	178,135
Waller	80			80
Wharton		30,000	7,000	37,000
Jackson	1,600	2,200	200	4,000
Matagorda		7,500		7,500
Fort Bend	3,800	9,110	3,500	16,410
Harris		454		454
Austin	1,000	500		1,500
Brazoria		3,000		3,000
Colorado				
District 11	6,480	52,764	10,700	69,944
Zapata			2,500	2,500
Starr		10,000		10,000
Webb			321	321
Willacy	10,000	80,000	20,000	110,000
Hidalgo	5,000	20,200	100,000	125,200
Live Oak		500		500
Cameron			190,000	190,000
Duval/Jim Hogg			2,354	2,354
District 12	15,000	110,700	315,175	440,875
Zavala	1,500	16,000	1,500	19,000
Frio		6,356		6,356
La Salle	2,500	448	7,000	9,948
Medina	377			377
Maverick		1,700		1,700
Uvalde		1,500		1,500
Atascosa			430	430
Dimmit		4,848		4,848

Table 5.--Texas cotton acreage treated with harvest-aid chemicals in
1977--continued

Counties	Desiccant	Defoliant	Combination	Total
District 13	4,377	30,852	8,930	44,159
San Patricio	7,200	22,500	42,816	72,516
Wilson	500	200		700
Nueces	67,260	9,653		76,913
Refugio			5,500	5,500
Jim Wells	5,000	2,000	1,000	8,000
Kleberg	500	500	9,000	10,000
Aransas	535			535
Bee			900	900
Calhoun	500		800	1,300
District 14	81,495	34,853	60,016	176,364
STATE TOTAL				
Districts 1-14	2,751,854	507,876	622,141	3,881,871

Table 6.--Number of cotton pickers and strippers operating in Texas in 1977^a

Extension District	County	Pickers	Strippers
1	Armstrong	0	7
	Collingsworth	0	280
	Deaf Smith	0	15
	Donley	0	275
	Gray	0	25
	Hemphill	0	4
	Randall	0	9
	Wheeler	0	200
	Total	0	815
2	Bailey	5	400
	Borden	0	150
	Brisco	0	500
	Castro	0	150
	Cochran	0	750
	Crosby	5	1,100
	Dawson	0	1,500
	Floyd	0	200
	Gaines	0	820
	Garza	3	192
	Hale	0	2,075
	Hockley	0	1,300
	Lamb	0	2,200
	Lubbock	3	1,550
	Lynn	0	1,500
	Parmer	0	200
	Scurry	0	350
	Swisher	0	450
	Terry	0	550
	Yoakum	5	325
	Total	21	16,262
3	Archer	0	6
	Baylor	0	75
	Childress	0	400
	Cottle	0	250
	Dickens	0	120
	Fisher	0	820
	Foard	0	23
	Hall	0	625
	Hardeman	0	150
	Haskell	0	800
	Jones	0	815
	Kings	3	80
	Kent	0	135
	Knox	3	100
	Motley	0	150
	Schackelford	0	20

Table 6.--Number of cotton pickers and strippers operating in Texas
in 1977^a--continued

Extension District	County	Pickers	Strippers
District 3--continued			
	Stonewall	0	100
	Throckmorton	0	28
	Wichita	0	20
	Wilbarger	0	500
	Young	0	22
	Total	6	5,239
4	Clay	0	61
	Collin	0	700
	Cooke	0	0
	Dallas	0	132
	Denton	0	15
	Ellis	0	1,000
	Fannin	0	40
	Grayson	0	12
	Hunt	0	250
	Jack	0	6
	Johnson	3	50
	Kaufman	0	196
	Montague	0	5
	Navarro	0	375
	Parker	4	0
	Rockwall	0	6
	Tarrant	0	32
	Wise	0	3
	Total	7	2,883
5	Delta	0	175
	Henderson	0	1
	Hopkins	0	4
	Lamar	0	30
	Rains	0	10
	Red River	0	8
	Van Zandt	0	9
	Total	0	237
6	Andrews	0	30
	Culberson	7	2
	El Paso	250	5
	Glasscock	0	135
	Howard	0	807
	Hudspeth	5	20
	Martin	0	460
	Midland	0	150

Table 6.--Number of cotton pickers and strippers operating in Texas
in 1977^a--continued

Extension District	County	Pickers	Strippers
District 3--continued			
	Pecos	20	24
	Presidio	0	0
	Reeves	20	50
	Regan	1	40
	Upton	0	40
	Total	303	1,763
7	Callahan	0	5
	Coke	0	4
	Coleman	0	30
	Concho	0	230
	Irion	0	2
	McCulloch	0	15
	Mitchell	0	400
	Nolan	2	210
	Runnels	0	850
	Schleicher	0	30
	Sterling	1	0
	Taylor	0	125
	Tom Green	0	650
	Total	3	2,551
8	Bell	0	750
	Bosque	0	13
	Brown	0	0
	Comanche	0	3
	Coryell	0	70
	Eastland	0	0
	Erath	0	6
	Hamilton	0	20
	Hill	0	1,500
	McLennan	0	300
	Palo Pinto	0	7
	Stephens	0	4
	Total	0	2,073
9	Freestone	0	5
	Houston	8	22
	Leon	0	6
	Total	8	33

Table 6.--Number of cotton pickers and strippers operating in Texas
in 1977^a--continued

Extension District	County	Pickers	Strippers
10	Bastrop	0	10
	Brazos	38	10
	Burleson	40	18
	Caldwell	0	25
	Falls	10	80
	Guadalupe	0	25
	Hays	0	2
	Lee	1	0
	Limestone	0	50
	Milam	32	800
	Robertson	35	6
	Travis	0	246
	Washington	0	2
	Williamson	0	1,200
	Total	156	2,574
11	Austin	10	20
	Brazoria	30	0
	Colorado	10	0
	Ford Bend	310	0
	Harris	4	0
	Jackson	18	1
	Matagorda	20	0
	Waller	1	0
	Wharton	900	2
	Total	1,303	23
12	Cameron	500	16
	Duval/Jim Hogg	16	6
	Hidalgo	465	4
	Live Oak	0	10
	Starr	50	5
	Webb	3	0
	Willacy	180	24
	Zapata	8	0
	Total	1,222	65

Table 6.--Number of cotton pickers and strippers operating in Texas
in 1977^a--continued

Extension District	County	Pickers	Strippers
13	Atascosa	0	430
	Dimmit	0	10
	Frio	0	0
	La Salle	0	30
	Maverick	6	0
	Medina	0	6
	Uvalde	10	3
	Zavala	80	10
	Total	96	489
14	Akansas	0	7
	Bee	0	12
	Calhoun	5	4
	Jim Wells	0	200
	Kleberg	5	20
	Nueces	42	86
	Refugio	25	10
	San Patricio	62	425
	Wilson	0	3
	Total	139	867
	Grand Total	3,264	35,874
	Total Counties	48	148

^a Compiled from county agents reports by Metzger, 1978 and Parnell, 1967.

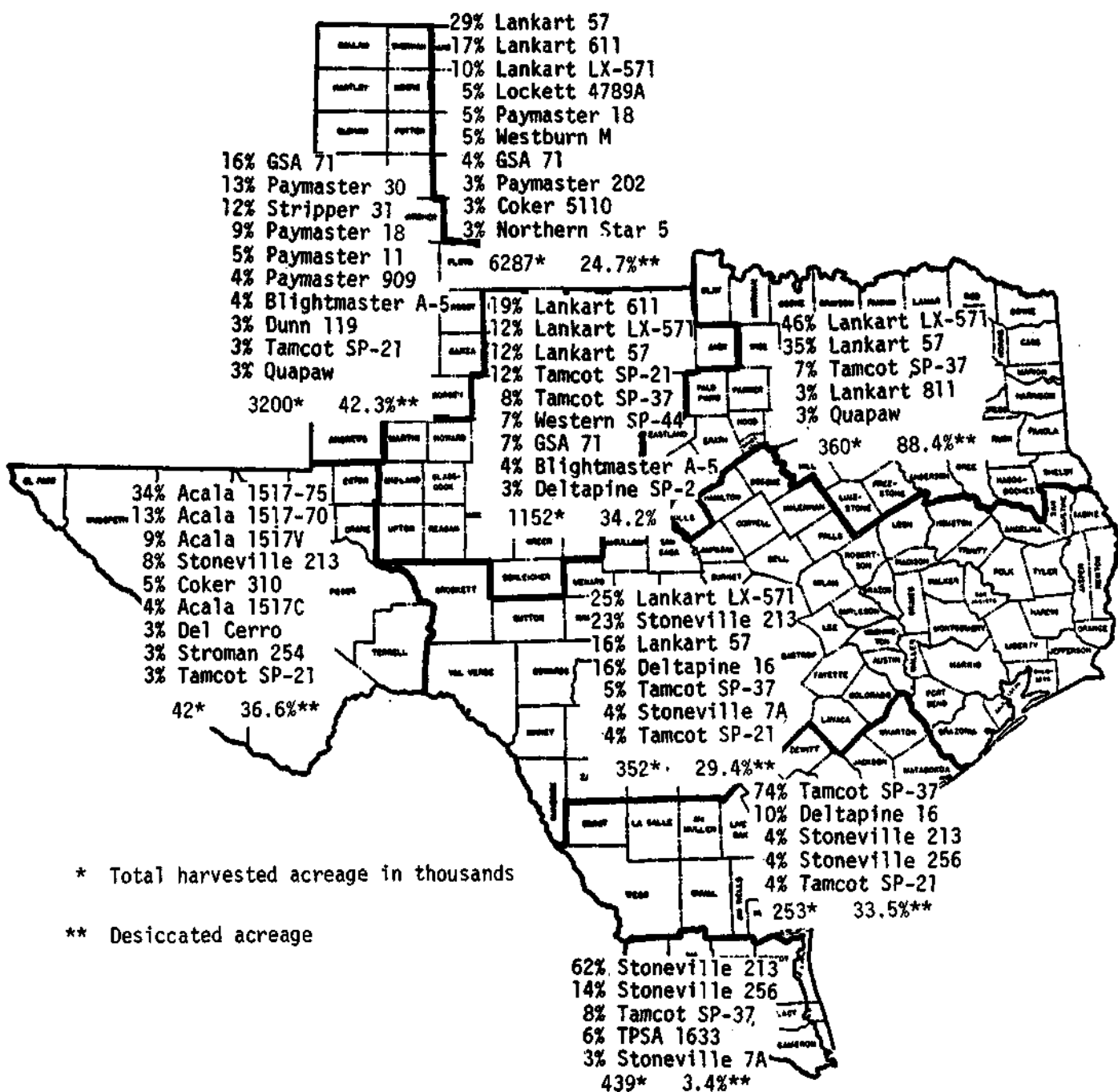


Figure 1. Map showing the areas of desiccant use in Texas in 1977 (Cotton Council International, 1978).

Table 7.--Regional cotton production practices, acreages and yields for Texas in 1977^a

Area	Type of Harvest	Harvested	Yield/ Acres	Total Production
		<u>1,000 Acres</u>		<u>Bales</u>
High Plains	Stripper	3,514	453	3,156,000
Rolling Plains	Stripper	1,483	342	1,144,900
C. Blackland	Stripper	584	298	290,400
Valley	90% Picker, 10% Stripper	438	472	431,000
Coastal Bend and Upper Coast	65% Stripper, 35% Picker	260	532	287,200
Trans Pecos	Picker	43	558	50,000
South Texas- Winter Garden	Picker	64	398	53,000
Total		6,386		5,413,000

Harvesting cost per bale:

Stripper \$25/bale

Picker \$45/bale

^a Source: Metzger, 1978.

Table 8.--Oklahoma cotton production^a

Year	Planted	Harvested	Yield	Production
	<u>1,000 Acres</u>	<u>1,000 Acres</u>	<u>Pounds/Acre Harvested</u>	<u>1,000 Bales</u>
1973	547	526	390	427
1974	570	547	272	310
1975	360	295	277	170
1976	350	335	251	175
1977	535	520	402	436
1978	605	585	292	355
1979 ^b	600	580	372	450

^a Oklahoma Crop and Livestock Rep. Serv. 1978.

^b Estimated August 1, 1979.

In over 95% of the spray operations, the field is treated only once in a season. The spray is applied by farm workers, farmers, or certified aerial applicators.

The annual exposure time of the ground rig or commercial aerial applicators would not normally exceed three 8-hour days per year. Crew members for loading the spray planes would be exposed for approximately six 8-hour days per year.

Aerial Applicator

In a survey conducted specifically for this assessment team report, questionnaires were sent to all members of the Texas Aerial Applicators Association. Replies were obtained from 63 businesses, 29 of which applied arsenic acid. Fifty-seven pilots averaged 20 hours each while applying 95,000 gallons of arsenic acid to an estimated 250,000 acres in 1977. The planes were loaded by 49 crew members who worked 2,209 hours or 46 hours each for an average of 6 days. All of the time was not spent in the actual pouring of the concentrate into the tanks.

All loading operations, whether ground rig or airplane, are done in the open. Each pilot applied arsenic acid to an average of 4,386 acres of cotton. The average acres treated by each ground rig would be about 100 acres and ranged from 10 to 500 acres.

Most of the aerial applicators surveyed, who used arsenic acid, answered the questionnaire. No more than 40 businesses are involved in Texas.

Extrapolations of total aerial applications based on the survey (29 of 40) are as follows: 1) Seventy-nine pilots applied arsenic acid to an estimated 342,618 acres in 20 hours each. 2) Planes were loaded by 68 ground crew members who worked 46 hours each within a month period.

Some exposure may be expected during maintenance, but there is no way to estimate the time of maintenance for changing of nozzles, related operations, or actual exposure.

According to Wolfe, et al. (1967), wind is the most important environmental condition influencing applicator exposure. The highest exposure value determined in his study was 552 mg/hr for an operator applying parathion in a fruit orchard with an air-blast sprayer. The application of 0.5 pound active ingredient of parathion with the use of a tractor-mounted boom ground sprayer in row crops, the same application means by which arsenic acid is applied, resulted in a mean dermal exposure of 4.7 mg/hr, and respiratory exposure of less than 0.01 mg/hr. The study reported dermal and respiratory exposures for 31 different work activities involving 10 different pesticides, but not arsenic acid. Exposure to arsenic acid will be similar to that received from the ground sprayer, not that reported for the air-blast sprayer.

The highest amount of As deposited on the coveralls of an aerial applicator was 1,880 mg after the applicator sprayed 450 gallons of arsenic acid in a period of 2 days. This exposure was mostly due to a leak in a line which resulted in a slow drip on one pant leg. This averaged 117.5 mg/hr. About one-tenth of the As received by the coveralls would reach the skin, and one-tenth reaching the skin would be absorbed; thus, $1.17 \text{ mg As/hr} \times 20 \text{ hr/yr} = 23.40 \text{ mg As/yr}$, $23.40 \text{ mg As/yr}/80\text{-kg individual} = 0.29 \text{ mg As/kg}$. The coveralls received the equivalent of 7.7 ml of spray over the 2-day period. No inhalation exposure is observed for the aerial applicators (Miller, et al., 1980).

Ground Crew Members

The highest amount of As from arsenic acid deposited on the coveralls of a ground crew member was 1,665 mg after loading 450 gallons of the 75% concentrate in 2 days. This averaged 104.06 mg/hr. It is hypothesized that one-tenth the amount on the coveralls would reach the skin and one-tenth on the skin would be absorbed, therefore: $1.04 \text{ mg} \times 8 \text{ hr} = 8.32 \text{ mg As/day}$. $8.32 \text{ mg As/day} \times 6 \text{ days loading} = 49.92 \text{ mg As/yr}$, $80 \text{ kg} = 0.62 \text{ mg As/kg total}$ for 6 days exposure per year. The ground crew member received the equivalent of 2.269 ml of the concentrate they were handling on their coveralls in 2 days time. No inhalation exposure is observed for ground crew member (Miller, et al., 1980).

Ground Rig Applicator

The highest amount of dermal As from arsenic acid received by a ground rig applicator in a recent survey (Miller, et al., 1980) was 1,378 mg after the applicator sprayed 240 gallons of arsenic acid in a period of 7.33 hours. This averaged 187.9 mg/hr. By EPA's assumptions, about one-tenth of that deposited on the coveralls would reach the skin, and about one-tenth of that reaching the skin would be absorbed. Therefore, $1.879 \text{ mg As/hr} \times 8 \text{ hr} = 15.0320 \text{ mg As/day} \times 3 \text{ days} = 45.096 \text{ mg As/80 kg man} = 0.564 \text{ mg As/kg total exposure}$ in a relatively short time per year. The applicator received a small amount (ca. 2.05 ml of total spray solution) of the spray deposited on the coveralls.

Some of the ground rig applicators wore an air sampler during the spraying of arsenic acid. The highest As content in air for inhalation exposure was 17 micrograms As/m³ during a ground spray application. This would be the equivalent of 0.002 ml of the spray being applied. The average ground rig applicator would spend about three 8-hour days spraying their fields. Thus, the possible inhalation exposure may be calculated as follows: $17 \text{ micrograms As/m}^3 \times 0.47 \text{ m}^3/\text{hr} \times 24 \text{ hr} = 232.5 \text{ micrograms total As}$ or about 0.0029 mg As/kg if no respirator was worn (Miller, et al., 1980).

Non-Applicator

The air that workers breathe during handling of arsenicals in commerce, or in Texas even during the ginning season was cleaner than that required by OSHA Standards. Attrep, et al. (1975) collected atmospheric As samples with Gelman Hurricane Air Samplers using Gelman Type A filter paper. The authors sampled approximately 100 m³; an average of 5 samples were taken each month and a heteropoly-molybdenum blue method for As analysis, which detects phosphate if it is present, was used. Even assuming that everything detected was As, which is dubious, only one of their values was above 0.05 microgram/m³ of air. OSHA (1978) set 10 micrograms/m³/8-hr day as the standard for As in air in the workplace.

Suta (1978) used Durrenberger's study (Durrenberger, 1975) of the particulate As emitted from cotton gins in Texas, as a basis for the assumption that 2,000 ppm As would be contained in the particulate matter emitted from cotton gins where arsenic acid was used. The value should be reduced to reflect the amount of As (50 to 450 ppm As) actually found in gin wastes (Miller, et al., 1975). Durrenberger did not have a sensitive means of detection and averaged only the higher values he could detect. The Durrenberger values were also used to extrapolate through modeling done by Youngblood to determine the amount of As emitted from gins. Suta (1978) used the number of gins in Texas as 1,040 in 1972 as a basis, whereas there are only 818

in 1978 (Price, 1978). All values calculated by Suta should be reduced by a factor of at least 5.

Oral exposure from arsenic acid to the general population arises from arsenic in treated cotton seed. The quantity of As in the daily diet due to arsenic acid is essentially zero.

Only glandless cottonseed is used as a human food source. It has a tolerance of 0.2 ppm As, the natural background level. No As can be used on cotton whose flour will be used for human consumption (FDA, 1964).

Bradicich, *et al.* (1969) reported values of arsenic in unrefined cottonseed oil as high as 1.33 ppm in a 1964 sampling. The amounts in refined oil are essentially zero. Further, cottonseed oil in the United States is mainly in salad oil, not in margarine and shortening. Only about 2% of margarine (Table 9, 10) is composed of cottonseed oil (Riepma, 1978). Over 80% of the cottonseed oil produced in the United States is exported. As a consequence, the amount of As from arsenic acid that could possibly be found in the U.S. diet would be so small as to be insignificant.

Even if it is falsely assumed that the unrefined oil was used in margarine whose average annual per-capita consumption is 9.3 pounds, only a relatively small exposure would result. The exposure may be calculated as follows: 9.3 pounds x 453.6 g/pound = 4,218.48 g, 4,218.48 g x 0.02 = 84.37 g annually of cottonseed oil. 1.33 micrograms As/g of unrefined oil x 84.37 g = 112 microgram As/yr, 112 micrograms As/yr/60 kg woman = 1.87 micrograms As/kg/yr. Pennwalt (1978) reported the highest amount of As contained in refined cottonseed oil from seed of As-treated fields to be 0.03 ppm. If this oil was used in margarine the annual exposure would be 0.042 microgram As/kg/yr. Thus, the total exposure through food equals 0.000042 mg As/kg/yr.

Total Exposure

By using the highest case and the average case, the total exposure of a ground rig applicator may be calculated as follows:

<u>Source</u>	<u>Highest case</u>	<u>Average case</u>	<u>Total exposure/year</u>
Food	0.000042	0.000042	9 pounds of margarine
Air	0.0029	0.0029	3 days
Dermal	0.564	0.04	3 days
<hr/>			
Total	0.567 mg/kg	0.043 mg/kg	

The greatest exposure is 1/176 of the No Effect Level of 100 mg As/kg suggested in the PD-1 (Federal Register, 1978) and the normal case is 1/2329 of the No Effect Level.

The average exposure (not the highest) determined from the overall study for ground rig applicators was calculated as 0.13 mg As/kg when it is assumed that his annual dose for a 3-day period was all received at the same instant. The average for the aerial applicators would be 0.06 mg As/kg, again assuming that the applicator's annual dose was received instantaneously. The average for the ground crew would be 0.30 mg As/kg again with the same assumption.

Table 9.--Fats and oils used in margarine, 1976

Month	Total Oils	Soybean	Corn	Cotton- seed	Safflower Seed	Peanut	Lard and Edible Tallow	Palm
- - - - - Million Pounds - - - - -								
January	210.1	176.3	20.1	5.6	1.3	D ^a	1.8	5.0
February	198.0	166.1	18.0	4.5	D ^a	D ^a	0.8	8.6
March	170.4	141.7	17.6	4.9	1.0	D ^a	1.3	3.9
April	155.1	127.2	17.3	2.5	3.1	D ^a	1.8	3.2
May	146.4	121.1	15.9	3.2	D ^a	D ^a	2.7	3.5
June	154.7	133.0	12.7	4.1	0.3	D ^a	1.9	2.7
July	159.6	127.9	18.0	3.7	D ^a	D ^a	3.2	6.8
August	153.3	125.6	18.8	3.9	D ^a	D ^a	2.0	3.0
September	157.0	125.1	19.8	4.1	0.7	D ^a	4.0	3.3
October	160.2	131.6	16.9	4.5	0.4	D ^a	6.8	D ^a
November	179.9	143.9	20.7	4.5	0.7	2.3	7.8	D ^a
December	188.1	151.6	22.1	4.6	D ^a	D ^a	9.8	D ^a
Totals	2,032.8	1,671.1	217.9	50.1	7.5	2.3	43.9	40.0

^a (D) Withheld to avoid disclosing figures of individual companies.

Source: Bureau of the Census, U.S. Dept. Comm., 1977.

Table 10.--Fats and oils used in margarine, 1977

Month	Total Oils	Soybean	Corn	Cotton- seed	Safflower Seed	Peanut	Lard and Edible Tallow	Palm
- - - - - Million Pounds - - - - -								
January	188.6	147.0	24.4	4.8	1.0	5.6	5.8	D ^a
February	180.5	148.2	24.4	4.3	D ^a	D ^a	3.6	D ^a
March	178.0	150.3	17.9	4.2	D ^a	D ^a	5.6	D ^a
April	152.6	123.6	18.6	3.8	D ^a	D ^a	6.6	D ^a
May	142.8	108.8	18.8	2.6	D ^a	D ^a	7.6	D ^a
June	142.9	111.1	14.9	3.6	D ^a	D ^a	8.4	D ^a
July	132.6	99.3	15.8	2.6	D ^a	D ^a	9.3	D ^a
August	158.8	122.2	20.4	3.3	D ^a	D ^a	8.2	2.9
September	166.9	130.1	19.8	3.6	D ^a	D ^a	8.1	5.3
October	177.5	146.0	19.6	3.4	0.4	D ^a	3.8	2.6
November	182.4	146.5	23.3	3.7	D ^a	D ^a	4.1	D ^a
December	194.9	152.4	25.6	4.5	D ^a	D ^a	8.7	D ^a
Totals	1,998.5	1,585.5	243.5	44.4	1.4	5.6	79.8	10.8

^a(D) Withheld to avoid disclosing figures of individual companies.

Source: Bureau of the Census, U.S. Dept. Comm., 1978.

For any particular application day the average ground rig applicator would receive the equivalent of 0.04 mg As/kg, the average pilot 0.02 mg As/kg, and the average ground crew member 0.05 mg As/kg.

Fate in the Environment

Air

The combustion of leaf trash which contained 2,000 ppm As resulted in about 76% of the As volatilizing into the air (Aboul-Ela and Miller, 1965). The form in which the As was released was not determined. The source of the leaf trash was cotton leaves from greenhouse-grown plants that were sprayed with ⁷⁴As-arsenic acid.

Burrus and Sargent (1976) suggested that As may be emitted during the burning of gin wastes. It was calculated that 84 kkg As were released during 1968 from the burning of gin wastes and 296 kkg As from burning of gin trash. These values are unrealistically high. The 84 kkg value was derived by assuming that 7.7 kg As/1,000 bales of cotton would be released and that the entire 10,857,000 bale United States crop for 1968 was treated.

Burning of gin trash has been illegal in Texas since 1973, and only one gin was issued a permit to burn gin trash in Texas in 1978 (Peters, 1979). If this gin was in the arsenic acid area and ginned 3 to 5 thousand bales, this would amount to only about 40 kg of As total emitted and this is 2,000 times smaller than the 84 kkg suggested by Burrus and Sargent (1976).

Oklahoma also does not permit the burning of gin wastes. In 1978, the Oklahoma Air Quality Control Board did not issue a single permit for burning of gin wastes (Gallion, 1979).

Based on the discussion above, very little As is emitted into the air from burning of gin trash.

Peters and Blackwood (1977) conducted a study to determine the amount of arsenic acid drift that would occur in the United States and concluded that there were 18.5 tons of arsenic acid considered as drift loss during 1971. The loss factors reported were 12.2 pounds/ton of arsenic acid applied. The exposed population estimate for the number of persons involved was 6,134. Texas and Oklahoma accounted for 98% of the arsenic acid used as a cotton desiccant.

Water

Richardson, et al. (1978) applied arsenic acid at the rate of 6.6 kg/ha to cotton. Arsenic in samples from the first run-off water ranged from 18 to 250 ppb depending on time and tillage after application. After 2 to 3 run-off events, the water content decreased to 10 to 20 ppb As.

Soil

Many soils contain native As. Arsenic acid will rapidly react with calcareous soils and act similar to phosphorus as far as availability is concerned. Once the As enters the soil, the fate is the same as that described in Volume I, Chapter 4 of this report.

The concentration in sediment averaged 20 ppm As and appeared to be related more to the As content of the soil than to the length of time or the tillage between As

application and the first run-off event (Richardson, *et al.*, 1978). By assuming average run-off and sediment yields, the amount of As that would be transported from a watershed by runoff and erosion is about 7% of that applied; however, part of the As moved from a watershed may be native As. The As contained in the 0- to 15-cm soil layer of the 3 watersheds studied averaged 8.45 ppm.

According to Fuller (1977), numerous factors influence the mobility of various ions in soil including: soil texture, pore space distribution, content and distribution of Fe, Al, Mn hydroxides and oxides, pH of soil, reduction/oxidation potential, soil organic matter and concentration of hazardous ions. Arsenic is listed as slowly mobile, similar to phosphorus. The most prominent mechanism of attenuation of As applied to soil is adsorption to the soil colloids.

The rate of accumulation or disappearance of As applied as arsenic acid which might be applied to Texas' soils is unknown. The Blacklands region of the State has highly calcareous soils which would tend to decrease the soluble As. The principal means by which As would enter the lower soil profile would be through the physical filling of cracks with dustier top soil which may contain higher As levels. The application of up to the legal limits of arsenic acid should only result in the addition of about 2 ppm As/year to the top 6 inches of soil that averages 8 to 10 ppm As normally. Inasmuch as no studies have been conducted to determine the rate of As disappearance through leaching or volatilization, the buildup rates are not known. The practice of rotation of cotton with grain sorghum, which is routinely done, should cut the As buildup in half, because arsenic acid would only be applied every other year and a theoretical increase of 1 ppm As/year would be the maximum.

Alternatives

Historically, the first desiccant used for cotton was pentachlorophenol (penta) which became established as a desiccant in 1950. Miller and Aboul-Ela (1969) found that amounts up to 2 ppm penta were accumulated in the seed of closed bolls when ¹⁴C-labeled material was sprayed on the greenhouse-grown plants.

The basic manufacturers of penta indicated that they sold more penta to one telephone pole processor than they did across the cotton belt. Because arsenic acid, due to its effectiveness and low price, was replacing penta the needed residue, feeding, and toxicological studies were not conducted. As a consequence, penta was lost as a cotton desiccant.

Paraquat is the only other desiccant registered for use on cotton and it is also proposed for RPAR. Paraquat was first marketed in 1967 for use as a cotton desiccant and as an additive to defoliants. Paraquat is formulated as a 2 pound active ingredient per gallon product and is registered for use up to 2 pints per acre. Miller, *et al.* (1980) report that paraquat used at rates up to 3 pints per acre was not as effective in desiccation of regrowth leaves as 2 pints per acre of arsenic acid. Lower amounts of paraquat have defoliation, but not desiccation properties.

Defoliants, wiltants, and regrowth inhibitors used as harvest-aid chemicals are not replacements for desiccants. The commercial defoliants include sodium chlorate, DEF, Folex, and Boll's-eye[®]. All of them with the exception of sodium chlorate are candidates for RPAR. Currently, three new cotton defoliants are being developed, but no new desiccants. The three defoliants are Uniroyal N-252 (Ames, *et al.*, 1974), trakephon (Cruz and Leiderman, 1974), and NorAm SN 49537 called Dropp. Miller, *et al.* 1971 tested a wiltant, NH 30C, a product of Esso Research and Engineering which was never fully developed for market.

Gardner and Troutman (1975) used 7.3 gallons/acre of Vapam applied in irrigation water to defoliate cotton and terminate its growth in California. The practice was not economical, but did prevent regrowth for 75 days. Cathey (1976) increased the defoliation response of cotton plants to the action of DEF and Accelerate in Mississippi tests with the use of TD 1123, a product of Pennwalt Corporation. Cathey and Barry (1977) also tried glyphosate in greenhouse tests. Glyphosate, although not registered, did inhibit regrowth.

Intense heat treatments, which consumed 10 gallons of LPG per acre, desiccated plants in some tests reported by Wheeler and Ford (1974). The heat treatments resulted in leaf desiccation. In basic studies, Bashford (1973) found that larger leaves were more heat-resistant than younger leaves. Leaf desiccation resulted from 0.6 cal/cm² of heat and ideal time-temperature exposure for defoliation response was 850 degree seconds above 130° F. At present, none of the major equipment manufacturers has started producing the units.

Miller and Aldred (1976) reported a new application technique aimed at increasing the effectiveness of desiccants. The technique involves the application of materials such as arsenic acid to the abraded stalks of the plants. Miller and Aldred (1977) reported a method for determination of the efficiency of application of arsenic acid to the abraded stalks.

Kirk, et al. (1972) reported harvesting stripper-types of cotton with a special broadcast cotton combine picker. All of the efforts of individuals such as Kirk and companies such as Ben Pearson and John Deere to develop harvesting equipment for use without desiccants have not resulted in the production of a commercial unit. Perhaps in the distant future someone will be able to perfect a harvester that will handle narrow-row cotton without desiccation, but it is not known how far in the future the accomplishment will become reality.

In recent efforts to determine if alternatives to desiccation could be used, application of a defoliant alone was not sufficient preparation of cotton at a Lyford, Texas test (Brendel and Miller, 1978). With ideal conditions and by using a variety of cotton that would easily defoliate, defoliation alone was sufficient preparation for cotton in a Sinton, Texas test. More recent extension of the studies indicates that it is only under special circumstances that defoliation alone is sufficient preparation of the plants for mechanical stripping. The growers cannot plant stripper-type cotton and hope that the one out of 10 years ideal conditions will be met so that they could harvest after defoliation only.

Frost will sometimes prepare cotton plants for mechanical stripping. Depending on weather conditions, most of the cotton on the High Plains of Texas is terminated by freezing temperatures in some years; however, waiting for a frost is not feasible in the southern parts of the State. Ray and Minton (1973) reported on the reduction of lint yields and the pronounced adverse effect on the color of the lint due to field weathering. The losses were higher at the beginning of the season, i.e., 3% per week. Yellowness of the lint increased with weathering, and the seed germination was reduced by exposure to weather due to delayed harvest.

In summary, at present there is no replacement chemical or new technique which is suited for preparation of cotton for mechanical stripping. Perhaps in the future new desiccants will be developed, the heated air technique will be improved, or changes in harvesting equipment will enable stripper harvesting without the application of a desiccant; the removal of either of the two or both of the commercial desiccants at present would be detrimental to the production of stripper cotton.

Insect Control As An Additional Biological Benefit

Pest management on about 1.7 million acres of Texas cotton today has been simplified by stripper harvest. The arsenic acid kills the growth of the plant, halts fruiting, allows the crop to be harvested in a short period of time, and kills the stalks. The food supply for boll weevils that are destined to overwinter is removed following application of arsenic acid and harvest.

The evolution of stripper harvest with its various components including arsenic acid brought those fundamental changes to the cotton agroecosystem with long-season cotton, picker harvest, and high insecticide treatments. All of the components, collectively, have become a substitute for insecticide treatments.

Because prompt areawide early harvests (and stalk destruction) are routinely followed in major cotton-growing areas in Texas, the boll weevil has dwindled to a problem of diminished significance. Successful over-wintering is difficult for the pest where the food sources required for winter survival are removed by stripper harvest. Boll weevil populations are so reduced in these areas that often no insecticide is required for control. If chemicals are used, the common practice is to apply only one or two applications. Bollworms and tobacco budworms, consequently, are far less of a problem. (Niles, et al., 1978; and Walker, et al., 1978.)

For this system to function, a harvest-aid chemical, with the properties of arsenic acid, is required. The loss of this component would negate the practicability of stripper harvest. In the absence of an arsenic acid, growers remaining in production would have only one option--they would return to longer season cottons and spindle-harvest. There is a wealth of experience to predict the increased insect problems, boll weevils and worms, that would spring from this production style where rapid harvest and prompt stalk destruction are impossible. The insecticide input would, without question, be increased.

Summary of Biological Analysis—Arsenic Acid

Arsenic acid is used on over 2 million acres of cotton grown in Texas and Oklahoma. It is used to desiccate the cotton plant prior to harvesting with a mechanical stripper. Low yields in this area necessitated the development of a production system that uses short-season varieties of cotton in which the bolls mature at the same time so that a once-over harvest is possible. Long-season varieties that use machine pickers are less economical where growing conditions may be unfavorable at harvest time, plant growth is limited, and yields are low.

In some years, an early killing frost will prepare the crop for harvest without the need for arsenic acid. In other years, alternatives may be suitable if there is no rainfall to stimulate new growth at harvest time; however, in all years, regardless of regrowth conditions, arsenic acid is the only desiccant that will effectively prepare the crop for harvest. Loss in the quality and quantity of both seed and fiber results if harvest is delayed or if complete desiccation of green leaves is not achieved. Green leaves in seed cotton stored in modules will raise the moisture content. The resulting high temperature causes a decrease in grade of cotton and seed through thermal degradation. At proper moisture levels (8 to 12%), cotton can be stored for a month without loss in grade or yield; however, severe losses can occur in 5 days if the moisture content is above 16% in the module.

Exposure to applicators is not large when proper safety techniques are employed. Dermal exposures were measured during application and results are as follows:

Operation	Exposure During Application		Annual Average	
	Highest	Average	Highest	Average
	- - - - mg As/kg/day - - - - -		- - mg As/kg/day - -	
Ground rig applicator	0.188	0.013 (for 3 days)	0.0016	0.0004
Aerial applicator	0.116	0.0088 (for 20 hrs)	0.0008	0.0002
Ground crew	0.103	0.0088 (for 6 days)	0.0017	0.0008

These levels are well below the No Effect Level of 100 mg/kg suggested in PD-1 (Federal Register, 1978).

No environmental problems have been associated with the use of arsenic acid when it is applied according to label directions. It will add about 1 ppm As to the surface 6 inches of soil each year. Cotton is used as a clean-till rotation crop with wheat, milo, or sorghum in some areas. Its use in the rotation helps to control Johnsongrass. Without cotton, the other crops could not be grown, because Johnsongrass could not be controlled. The use of arsenic acid allows cultural practices which reduce insect populations and resulting insecticide use. In some cases no insecticide is necessary.

A summary of testimonial letters solicited from the Texas Agricultural Extension Service is summarized in Table 11. Responses of some individuals are also included even though their inputs were not requested.

Economic Impact Analysis of Cancelling Arsenic Acid

Arsenic Acid—Cotton Desiccation

Current Use Analysis

Arsenic acid is registered for use as a harvest aid on cotton. Specifically, it is used to desiccate the plant in preparation for mechanical harvesting, primarily with a stripper-type harvester. Although the use of arsenic acid as a cotton desiccant dates to 1956, its utility to Texas and Oklahoma cotton growers has been amplified with the development of the short season production system and the module process for storing bur cotton prior to ginning.

According to preliminary results from an unpublished survey conducted for USDA in 1977, approximately 1.4 million acre-treatments of arsenic acid were applied in that year. At the most commonly used rate of application (3 pints or 4.4 pounds a.i. per acre), total usage was approximately 5.9 million pounds of active ingredient (Table 12).

As indicated in Table 4, sales and thus use of arsenic acid differs considerably from year to year, varying from a high of 1,159,000 gallons in 1973 to a low of 470,000 gallons in 1976. The 1977 sales of 700,000 gallons are approximately 20% less than the average sales (880,000 gallons) for the period 1964-77, because there was a strike by the lead smelter workers in that year which curtailed production of

Table 11.--Summary of testimonial letters for the use of arsenic acid in cotton production^a

Name ^b	P/I/Co ^c	1	2	3	4	5	6	7	8	9	10	11	12	
L. Linney	P		X		X	X		X	X					<u>Column Headings</u>
M. A. Burkholder	P		X	X				X	X	X	X			1. Loss of arsenic acid will cause loss to self.
W. Roberts, Jr.	P		X	X	X	X		X	X		X			2. Loss of arsenic acid will cause loss to county.
D. E. Reue	P		X	X	X	X		X	X		X			3. Loss of arsenic acid will cause severe economic impact on product.
R. Upshaw	P		X		X	X		X	X		X			4. Loss of arsenic acid will cause loss in grade of cotton.
H. G. Hoermann	P		X					X	X		X			5. Loss of arsenic acid will cause loss to cotton yield.
L. E. Winkler	P		X	X	X	X		X			X	X		6. Loss of arsenic acid will cause loss to seed quality.
B. L. Greenway	P		X	X	X	X	X	X	X	X	X			7. Want to retain arsenic acid use.
W. E. Ruth	P		X	X	X	X		X	X				X	8. Alternative measures are not as good as arsenic acid.
J. R. Supak	P				X	X	X		X					9. Arsenic acid is cheaper than alternatives.
V. A. Walton	P		X	X	X		X	X	X		X			10. No alternative crops are available.
R. Corbin	P		X	X	X	X					X			11. Have had no trouble with use of arsenic acid.
J. R. Supak	P		X	X				X	X					12. Loss of arsenic acid will increase insect problem.
C. W. Green	P		X		X	X	X	X	X	X	X	X		
B. R. Percival	P		X	X					X	X				
D. Reeves	P		X	X	X	X		X				X		
J. D. Swift	P		X	X	X	X		X	X					
D. Doggett	P		X					X	X		X			

Table 11.--Summary of testimonial letters for the use of arsenic acid in cotton production^a--continued

Name ^b	P/I/Co ^c	1	2	3	4	5	6	7	8	9	10	11	12	Column Headings
B. McCutchen	P		X	X	X	X		X	X		X			
W. B. Griffith	P		X	X	X	X	X	X	X		X		X	1. Loss of arsenic acid will cause loss to self.
G. Sears	P		X	X				X	X	X				2. Loss of arsenic acid will cause loss to county.
B. Filty	I	X	X	X				X			X			3. Loss of arsenic acid will cause severe economic impact on product.
M. Cheek	I	X	X	X	X	X		X	X	X	X			4. Loss of arsenic acid will cause loss in grade of cotton.
B. Mahe	Co		X	X										5. Loss of arsenic acid will cause loss to cotton yield.
R. Butler	I	X							X		X			6. Loss of arsenic acid will cause loss to seed quality.
J. Griggs	I	X		X	X	X	X		X		X			7. Want to retain arsenic acid use.
V. L. Kelly	I										X			8. Alternative measures are not as good as arsenic acid.
R. Green	I	X	X	X	X	X	X	X		X				9. Arsenic acid is cheaper than alternatives.
J. R. Watkins	I		X	X					X			X		10. No alternative crops are available.
R. M. Clack	I	X	X	X					X					11. Have had no trouble with use of arsenic acid.
M. and K. Thornton	I	X	X	X				X	X	X				12. Loss of arsenic acid will increase insect problem.
W. E. Malone	I		X	X				X			X			
E. Lowrey	I	X	X	X				X	X		X	X		
D. Clinard	I	X	X	X				X				X		
G. Clinard	I	X							X	X				

Table 11.--Summary of testimonial letters for the use of arsenic acid in cotton production^a--continued

Name ^b	P/I/Co ^c	1	2	3	4	5	6	7	8	9	10	11	12	<u>Column Headings</u>
F. London	I	X												
P. Lowrey	I	X						X						1. Loss of arsenic acid will cause loss to self.
J. Lowrey		X	X	X	X	X	X	X						2. Loss of arsenic acid will cause loss to county.
A. L. Cooper	I	X	X					X						3. Loss of arsenic acid will cause severe economic impact on product.
A. Z. Puckett	I	X	X					X	X					4. Loss of arsenic acid will cause loss in grade of cotton.
Total Responses (40)		15	33	27	19	18	8	29	27	9	20	6	2	5. Loss of arsenic acid will cause loss to cotton yield.
														6. Loss of arsenic acid will cause loss to seed quality.
														7. Want to retain arsenic acid use.
														8. Alternative measures are not as good as arsenic acid.
														9. Arsenic acid is cheaper than alternatives.
														10. No alternative crops are available.
														11. Have had no trouble with use of arsenic acid.
														12. Loss of arsenic acid will increase insect problem.

^a X indicates that the topic was mentioned in letter. A blank indicates no mention of topic in letter.

^b For more information on the respondents, see references.

^c P = Professional from Extension Service; I = Individual farmer; Co = Company.

Table 12.--Estimated use of cotton desiccants by region for 1977

Region	Cotton Planted Acres ^a	Total Desiccated Acres	Arsenic Acid- Treated Acres ^b	Arsenic Acid Acre Treatments ^b	Arsenic Acid Pounds a.i. Applied ^c	Paraquat- Treated Acres ^d	Paraquat Acre Treatments ^e	Paraquat Pounds a.i. Applied ^f
- - - - - <u>Thousands</u> - - - - -								
Coastal	696	416	291	315	1,386	125	135	34
Blacklands	593	511	476	479	2,108	35	38	10
Rolling Plains and Oklahoma	1,813	588	333	339	1,492	255	275	69
High Plains	3,486	1,588	220	220	968	1,368	1,478	370
Trans-Pecos	166	11	0	0	0	11	12	3
Total	6,754	3,114	1,320	1,353	5,954	1,794	1,938	486

^a 1977 Texas Cotton Statistics, Oklahoma Cotton County Estimates 1977, New Mexico Agriculture Statistics 1977, Arizona Agricultural Statistics 1977.

^b Preliminary data from unpublished survey conducted for USDA in 1977.

^c Derived by multiplying acre treatments by the maximum recommended application rate of 4.4 pounds a.i. per acre.

^d Estimated from unpublished survey conducted for USDA in 1977.

^e Assessment Team estimate.

^f Derived by multiplying acre treatments by 0.25 pound a.i. per acre, the common rate of application.

arsenic acid. Results from an industry survey (Pennwalt, 1979) indicate relatively little annual variation in arsenic acid use in either the Blacklands or the Coastal region. Thus, it is the Texas Plains and Oklahoma which accounts for the considerable annual variation in arsenic acid use cited previously. This fluctuation would appear to be due mainly to varying weather conditions (Supak, 1978).

Use Impacts

Short-Season Production System.--The short season production system, as recommended by the Texas Agricultural Extension Service, (Metzer, 1979) consists of the following six elements:

1. Selection of short-season (120-140 days), determinate varieties of cotton.
2. Early planting.
3. Management of irrigation water (if used) and fertilizers (primarily with regard to nitrogen use) to promote early maturity.
4. Early season insect control with IPM approach: This implies chemical treatment as a curative rather than a preventive, first for fleahopper, and subsequently for boll weevil when the cotton is squaring. Such procedure presupposes good scouting practices.
5. Narrow-row pattern: With greater plant density, relatively more bolls mature early at any given level (height) of the plant. Here again the objective is early maturity, hence early harvest.
6. Early destruction of postharvest crop residues to reduce the number of diapausing boll weevils. To the extent that such over-wintering populations are reduced, the need for boll weevil insecticides in the following crop season is diminished. This in turn conserves the population of beneficial insects which prey upon Heliothis spp.

Thus, the key element in the short season production system is earliness, early planting, early treatment for insects, and early destruction of crop residues. To ensure early harvest, a desiccant is used to crack immature bolls and to kill the cotton plant.

Short-season practices have also received the attention of States other than Texas and Oklahoma, and thus may have the potential of becoming the universal basis of IPM approaches to profit maximization in cotton production. The record to date lends validity to the belief that potential (future) benefits of a more widely adopted short-season system far outweigh benefits currently realized.

In response to processing constraints at the gin induced by the evolution of rapid harvest machinery (eg., 4-row strippers), Cotton Incorporated developed what is known as the module process for storing bur cotton adjacent to the field prior to ginning. In the module process, growers can harvest as fast as weather conditions permit, without spending time in line at the local gin. Rapid harvest capacity also facilitates early crop residue destruction which reduces insect damage in the following season; however, if the bur cotton placed in the module contains greater than 16% moisture (whether due to atmospheric moisture or the presence of green leaf or stem trash) (Metzer, 1979a), it will not store properly; and thus a substantial loss in both seed and fiber quality is likely. To minimize such losses, extension agents recommend that the moisture level at harvest should not exceed 12%. Given this concern, an effective desiccant is essential for stripper harvesting.

Lest the impression be given that the module system has no disadvantages, it should be noted that its adoption entails new investments of a substantial magnitude.

The grower must purchase a module builder (special compactor), at a cost of approximately \$20,000, and the ginner must purchase specialized intake equipment to handle the modules (Southwest Farm Press, 1979). In addition, transport of the modules from field to gin requires the acquisition of a flatbed tractor-trailer (such purchase to be made by either the grower, the ginner, or some third party entrepreneur).

Adoption of the module technology has been rapid in Texas. Whereas in 1974, only 3% of Texas cotton was moduled, by 1978 this had risen to 23% (USDA, 1974-79); however, this system would result in increased harvesting costs for smaller growers. Reportedly, one module builder can accommodate two strippers--which implies an annual harvest capacity of approximately 370 acres² per crop season. Though many growers exceed this acreage (especially in the Texas Plains), a substantial proportion of growers (especially in the Blacklands) have considerably less cotton acreage.

Alternatives to Arsenic Acid.--Paraquat and a killing frost are arsenic acid alternatives for certain regions within Texas and Oklahoma. Paraquat is a chemical alternative applied at a rate of 0.125 to 0.25 gallons (.25 to .50 pounds a.i.) per acre at a cost of \$40.00 per gallon. Producers in the Blacklands and Coastal regions of Texas would apply paraquat at a rate of 0.25 gallons per acre (Table 13).

It should be noted that the quantity of paraquat used in the Texas Plains and Oklahoma in 1977 (Table 12) was atypically high--a situation brought about by two factors. First, weather conditions were such that cotton matured earlier than usual, thus creating an unusually high demand for arsenic acid. Second, in view of the limited supply in 1977 (see above) growers apparently substituted paraquat for arsenic acid.

As explained previously, defoliants cannot be substituted for desiccants in the preparation of cotton for stripper harvesting. Although paraquat has defoliant properties (Miller, et al., 1968), its primary mode of action is as a desiccant, and it is designated as such by the Texas Agricultural Extension Service (Metzer and Supak, 1975). Among the variety of harvest aids available, only paraquat and arsenic acid are desiccants; therefore, in the ensuing analysis, paraquat is considered to be the only chemical alternative to arsenic acid.

In the Texas Plains and Oklahoma, growers generally rely upon a killing frost (28° F or less) to desiccate the cotton crop. Because the Blacklands and the Coastal regions may not receive a killing frost (National Oceanic Atmos. Admin., 1968-78), however, frost cannot be considered an alternative to arsenic acid in these regions.

Use Patterns.--Usage patterns of arsenic acid (Table 14) indicate substantial differences in the relative importance of arsenic acid as a cotton desiccant in three different regions: Coastal Bend and Lower Valley; Blacklands; and the Texas Plains and Oklahoma. Consequently, the economic impacts of the cancellation of arsenic acid will be determined for each region.

² Derivation: (FEDS Budgets, 1977) Purchase price of new stripper = \$8,715; depreciation per hour = \$7.058; performance rate of stripper = .667 hours per acre. Hence: $\$8,715 \div \frac{\$7.058}{\text{hr.}} = 1234.77 \text{ hours}$; $1234.77 \text{ hours} \div 10 \text{ yrs.} = 123.48 \text{ hrs./yr.}$; $\frac{123.48}{\text{year}} \text{ hrs.} \times \frac{1 \text{ acre}}{0.667 \text{ hrs.}} = 184.30 \text{ acres}$; $\frac{184.3 \text{ acres}}{\text{year}} \times 2 = 369 \text{ acres per year.}$

Table 13.--Change in treatment cost when substituting paraquat for arsenic acid

Item	Unit	Arsenic Acid (All Regions)	Paraquat			
			High Plains	Rolling Plains and Oklahoma	Blacklands	Coastal
<u>Chemical</u>						
Price	\$/gal.	6.00	40.00	40.00	40.00	40.00
Rate	gal./acre	0.375	0.125	0.188	0.250	0.250
Cost	\$/acre	2.25	5.00	7.50	10.00	10.00
Change	\$/acre	--	2.75	5.25	7.74	7.74
<u>Change in application cost</u>						
Aerial	\$/acre	--	0.25	0.25	0.25	0.25
Ground	\$/acre	--	--	--	--	--
<u>Change in treatment cost</u>						
Aerial	\$/acre	--	2.50	5.00	7.50	7.50
Ground	\$/acre	--	2.75	5.25	7.75	7.75
<u>Method of arsenic acid application</u>						
Aerial	Percent	51	54	38	89	2
Ground	Percent	49	46	62	11	98
<u>Average change in treatment cost</u>						
Change	\$/acre	--	2.62	5.16	7.53	7.74

Table 14.--Relative importance of arsenic acid and desiccation practices
to cotton production in Texas and Oklahoma, 1977^a

Region	Cotton Acreage Base	Proportion of Acres Treated With:				
		Harvest Aid ^b	Defoliant ^c	Desiccant	Paraquat	Arsenic Acid
----- <u>Percent</u> -----						
Coastal	planted	86 ^d	80	60	18	42
	treated	100	93	69	21	49
	desiccated	NA ^e	NA	100	30	70
Blacklands	planted	98	19	86	6	80
	treated	100	20	88	6	82
	desiccated	NA	NA	100	7	93
Rolling Plains and Oklahoma	planted	33	2	32	14	18
	treated	100	7	97	42	55
	desiccated	NA	NA	100	43	57
High Plains	planted	49	6	46	39	6
	treated	100	12	94	81	13
	desiccated	NA	NA	100	87	13
Trans-Pecos	planted	11	4	7	7	0
	treated	100	40	60	60	0
	desiccated	NA	NA	100	100	0
Total	planted	52	14	46	27	20
	treated	100	27	89	51	38
	desiccated	NA	NA	100	58	42

^a From Table 12.

^b This includes defoliants and desiccants.

^c Unpublished survey conducted for USDA in 1977.

^d Read as 86% of cotton acreage planted is treated with a harvest aid.

^e NA: Not applicable.

Assumptions and Procedures for the Economic Analysis

Blacklands.--In view of comparative efficacy data (i.e., arsenic acid vs. paraquat) and given the relative non-availability of pickers in the Blacklands, some assumptions must be made in order to estimate the impact of arsenic acid cancellation in this region:

- 50% (or 238,000 acres) of the cotton acreage treated with arsenic acid in the baseline year of 1977 (476,000 acres) will instead be treated with paraquat, and will be successfully stripped and ginned;
- 40% of the cotton acreage treated with arsenic acid in 1977 will be treated with paraquat, but due to the presence of substantial quantities of green leaf material, will not be ginned. There will be a total loss of output on this acreage;
- 10% of the cotton acreage treated with arsenic acid in 1977 will be treated instead with paraquat, but will be picked (as opposed to stripped), with an associated yield loss of 25% (Parvin, et al., 1979) owing to the lack of a second picking.

The assumptions regarding the acreage that can be successfully stripped are only subjective estimates; thus, it is essential to determine the sensitivity of the aggregate regional impact to variations in these assumptions. Hence, the aggregate impact will be stated as a range of values.

Although the impacted acreage that will be picked cannot be documented, it nevertheless has some empirical basis. In 1977, an estimated 45 pickers were used in the Blacklands (Table 6). If one assumes a performance ratio of 0.788 hr/acre for a 2-row picker (FEDS Budgets, 1977), a harvest season of 120 days (Texas Crop and Livestock Rep. Serv., 1968-78) at 6 to 8 hours of operation per day (Metzer, 1979), this number of pickers implies an annual harvest capacity of approximately 48,000 acres. When it is further assumed that the 35,000 paraquat-treated acres in the Blacklands (Table 12) are picker harvested, there would appear to be about 13,000 acres of "excess picker capacity" available for use on acreage currently treated with arsenic acid.

Finally, in two counties adjacent to the Blacklands (Robertson and Brazos Counties), there were 73 pickers in use on 24,800 acres (Table 6; Texas Crop and Livestock Rep. Serv., 1968-78) in 1977, a fact which implies an excess picker capacity of some 53,000 acres.³ With a total excess capacity of 66,000 acres (13,000 + 53,000), there would appear to be sufficient picker capacity to harvest once-over at least 10% (i.e., approx. 48,000 acres) of the acreage currently treated with arsenic acid, assuming that the pickers are sufficiently mobile.

³ Derivation: $\frac{73 \text{ pickers} \times 120 \text{ days}}{0.788 \text{ hr/acre}} \times 7 \text{ hours/day} = 77,800 \text{ acres};$

$77,800 - 24,800 \text{ acres} = 53,000 \text{ acres}.$

The following prices and technical parameters will be used in the subsequent estimate of economic impacts in the Blacklands:

Cotton yields (Texas Crop and Livestock Rep. Serv., 1968-78):

225 pounds lint/acre

365.6 pounds seed/acre

Harvest aid treatment costs: Table 13

Custom harvest rates (Table 7): \$25/bale (\$0.011/pound) for stripping

\$45/bale (\$0.029/pound) for picking

Ginning costs (including bags and ties) (Lovell, 1979):

\$2.05/cwt of seed cotton (Note: On the average, 2,225 pounds of stripped seed cotton yields a 480-pound bale of lint)

Associated marketing services (USDA, 1979a):

Charges for receiving at the warehouse are \$1.64/bale, plus storage charges at \$1.00/bale/month for an average storage period of 3 months.

Cotton prices (Texas Crop and Livestock Rep. Serv., 1968-78):

\$0.519/pound lint

\$87.75/ton (\$0.04388/pound) for seed.

Coastal Regions.--The analysis of the Coastal region is divided into two distinct sub-regions: The Coastal Bend and the Lower Valley (Figure 2). These are geographically distinct regions with different average yields and cultural practices. The impact on each sub-region is calculated separately.

The short-season system is a relatively new practice that was implemented in the Coastal Bend region as recently as 1974. Results from agricultural research in short-season concepts led to the rebirth of the cotton industry, as shown in Figures 3 and 4. From the 1969 period through 1975, cotton acreage in the Coastal Bend fell from 155,000 acres of dryland plus 8,000 acres of irrigated to 54,000 acres of dryland and 1,000 acres irrigated. This decrease is an average of approximately 16,000 acres per year. Beginning in 1974, the introduction of the short-season practices resulted in the yield increasing from 200-300 pounds per acre to 450 to 550 pounds per acre (Texas Crop and Livestock Rep. Serv., 1968-78a).

The foregoing discussion provides information on the adoption of arsenic acid as part of the short-season system, but it does not provide any indication on the impacts of change from arsenic acid to an alternative. Discussions with cotton production specialists on the Assessment Team indicated they could not estimate the relative efficacy of paraquat versus arsenic acid. Therefore, the economic impact on the Coastal region will contain an estimated minimum and maximum impact of an arsenic acid cancellation, which are based on minimum and maximum estimated differences of efficacy between arsenic acid and paraquat.

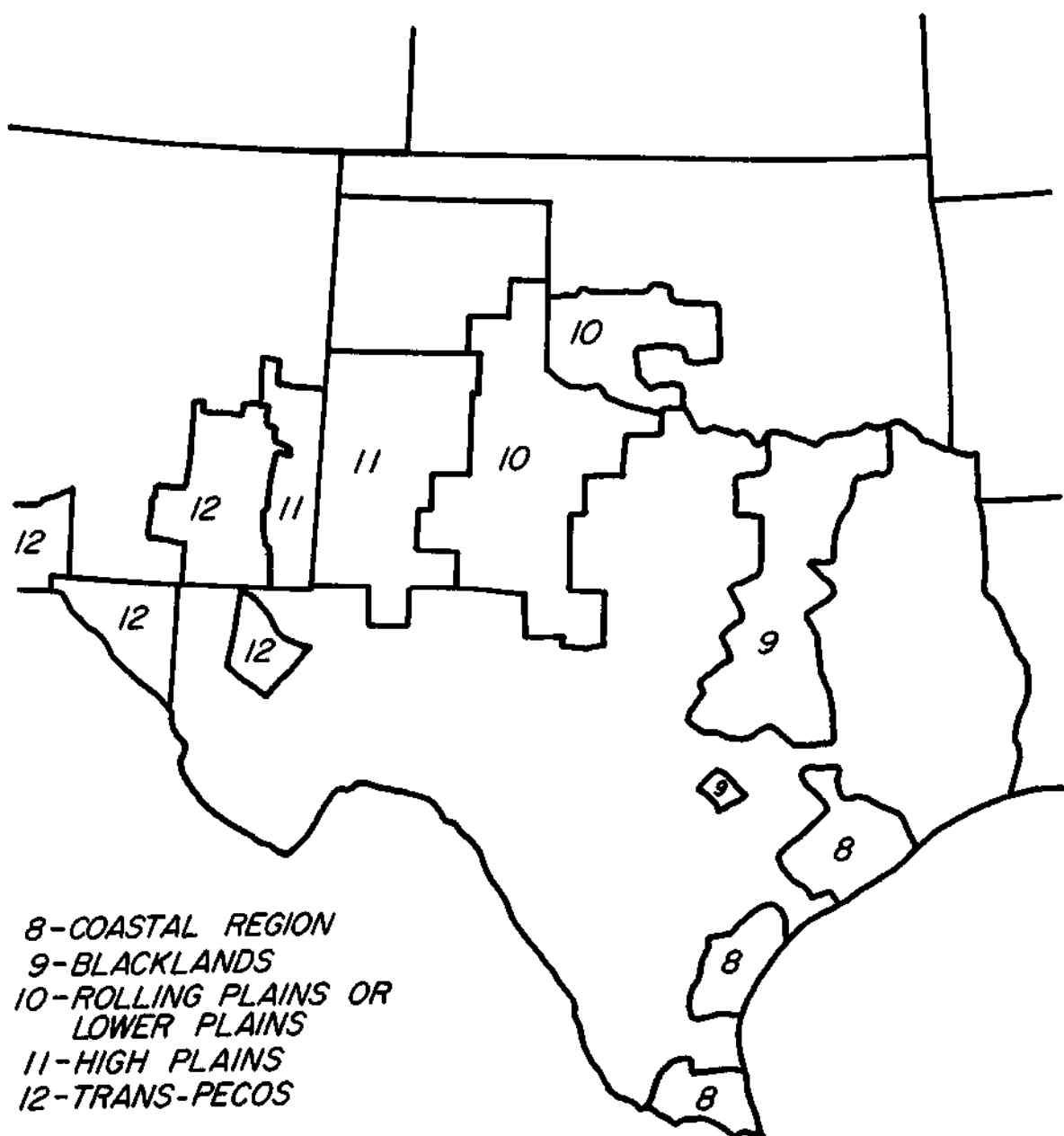


Figure 2. Map of summary regions for 1977 USDA survey of pesticide use on cotton.

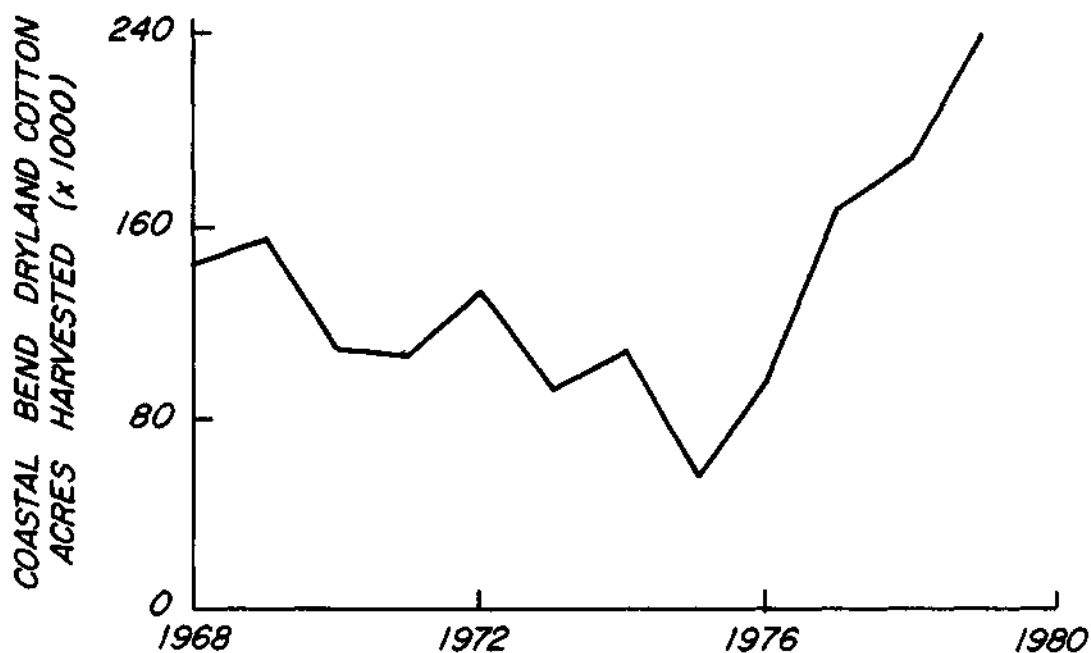


Figure 3. Acres harvested of dryland cotton in the Texas Coastal Bend district, 1968-1979.

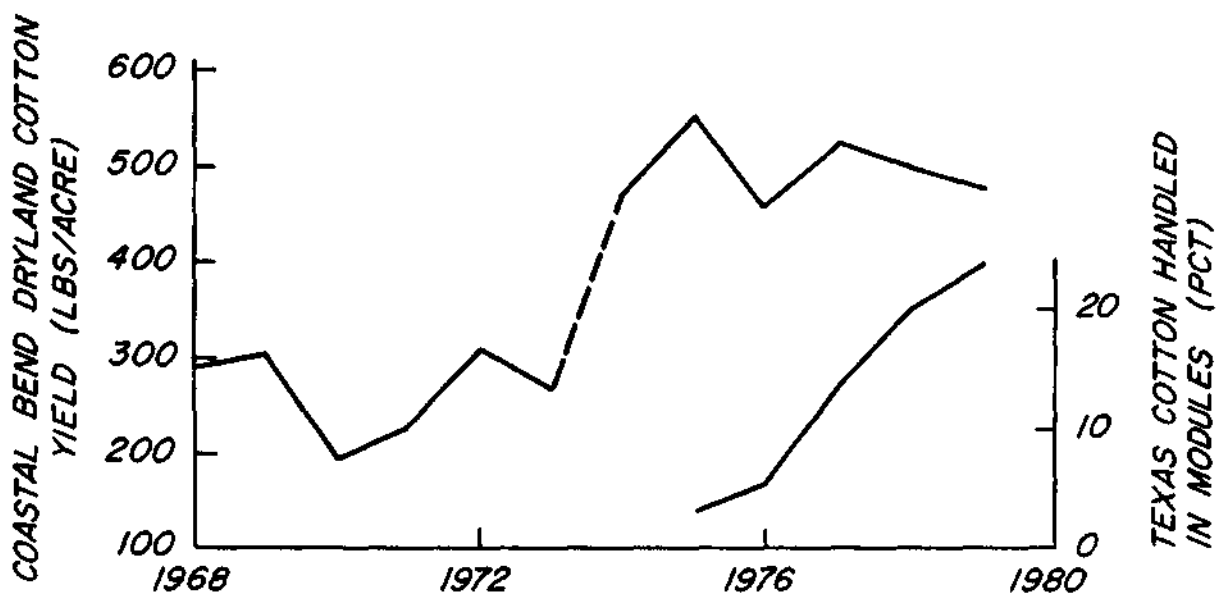


Figure 4. Yield of cotton in the Texas Coastal Bend district, 1968-1979 and the proportion of Texas cotton moduled, 1975-1979.

The minimum partial budget estimate of the economic impact in the Coastal region is based on the following assumptions by the Assessment Team:

1. All 291,000 acres of arsenic acid-treated cotton in the Coastal regions were managed under the short-season system: 170,000 acres in the Coastal Bend and 121,000 acres in the Lower Valley.
2. Paraquat, when applied at a sufficiently high dosage, is equally effective as arsenic acid. This rate is 2.0 pints per acre in the Coastal regions.
3. Arsenic acid is applied at 3 pints per acre.

A maximum estimate of the partial budget impact is useful for establishing an upper bound for the expected economic impact. This maximum estimate assumes that weather conditions will be unfavorable and that producers will absorb the impact without substantially modifying their production decisions. If growers continue to produce cotton, the production adjustments are limited and depend upon regional characteristics.

The maximum partial budget estimate for the Coastal Bend and Lower Valley regions is based on the following assumptions by the Assessment Team:

1. All 291,000 acres of the arsenic acid-treated cotton in the Coastal regions were managed under the short-season system: 170,000 acres in the Coastal Bend and 121,000 acres in the Lower Valley.
2. With the cancellation of arsenic acid, a quality decrease equivalent to a yield loss of 3% would occur during the first year in the Lower Valley, and during the first 2 years in the Coastal Bend. Although the members of the Assessment Team were unable to project the magnitude of this loss, they nevertheless accepted 3% as a reasonable estimate. Such losses are the result of harvest delays imposed by a temporary shortage of pickers.
3. A further ramification of the temporary shortage of pickers would be the sacrifice of a second picking in the Coastal Bend for the first year with a resulting yield loss of 25%. Given that pickers are presently more widely used in the Lower Valley than in the Coastal Bend, no such losses are projected in the former region.
4. The reversion to picker-type cotton varieties (i.e. long season) will entail a yield loss of 10% on all acreage beginning in the second year following cancellation.

Based on their professional experience, the members on the Assessment Team made the following additional assumptions:

1. Insect treatment costs would be \$19.60 higher after the first year of impact. Without arsenic acid as a dessicant, the growing season would lengthen with subsequent increased time for the bollworm/budworm complex to increase populations that would overwinter. This cost estimate was made by the Assessment Team and was based on costs without short-season technology.
2. Paraquat will be used at a rate of 2 pints per acre.

3. An average of 25% of the impacted acreage will be adequately prepared for stripper harvest. The remainder will be machine-picked with acreage picked twice (once in the Coastal Bend the first year due to a picker shortage).
4. Harvest costs will increase by \$15.50 per acre with the shift to machine picking (\$20.00 for the first year following cancellation in the Lower Valley). This impact would be due to the increased costs of two pickings per acre. Picker scarcity in the Coastal Bend region would result in only one picking during the first year with no increased picker costs, but yields would decline 30%.

Texas Plains and Oklahoma.--Growers in Oklahoma and the Texas Plains rely primarily upon frost for harvest preparation. The impact of canceling arsenic acid can be measured in terms of weathering losses sustained on that portion of the cotton crop that matures prior to the first hard-freeze date.⁴ Implicit in the foregoing procedure is the assumption that acreage treated with a harvest aid chemical approximates acreage harvested before the mean freeze date. This cannot be verified in any rigorous sense, but there is nevertheless some evidence supporting this contention.

For the period 1964-76, the annual average sales of arsenic acid were estimated at 813,000 gallons,⁵ which implies (over the long run) the annual treatment of approximately 2.17 million acres ($813,000 \text{ gal.} \div 0.375 \text{ gal.} = 2.17 \text{ million acres}$). When the 767,000⁶ acres treated with arsenic acid in the Blacklands and Coastal Bend regions (Table 12) are subtracted from this total, the remainder of 1.4 million acres represents the annual average treatment in the Texas Plains and Oklahoma.

⁴ The mean first hard-freeze date (for convenience, referred to hereafter as "mean freeze date") was calculated in the following manner: For each year in the period 1968-78, the number of days was observed between an arbitrary date (e.g. Oct. 1) and the first fall day on which the temperature falls to 28° or less. Annual temperatures follow a normal distribution (Orton, 1979), and therefore an arithmetic mean can be calculated from the annual observations. Thus, if on the average a hard freeze occurs 50 days after Oct. 1, the mean freeze date would be Nov. 20.

⁵ The annual average sales of arsenic acid for the period 1964-77 was reported to be 880,000 gallons (Table 4). Missing from this time series, however, are data for 1971, 1972, and 1975-years when the percentage of acres harvested prior to the freeze date was low. Moreover, due to a strike in the lead smelting industry in 1977, production and sales of arsenic acid were unusually low for that year. Given the foregoing distortions, the observation for 1977 was dropped. Subsequently, sales for the missing years were estimated by regressing cotton acreage harvested on gallons of arsenic acid sold ($b = +0.105480$, $s(b) = 0.08118$; $t = 1.299$). It should be noted, however, that the foregoing estimate of (b) is significant only at (approximately) the 0.88 level.

⁶ It is assumed that the acre treatments in 1977 are representative of the annual average for these two regions. First, results from a recent survey (Pennwalt, 1979) have shown the percentage of acreage treated with arsenic acid to be relatively stable over the period 1971-78. Second, because the cotton harvest begins as much as 2 months earlier in the Blacklands and Coastal Bend regions than in the Texas Plains and Oklahoma, it is highly likely that the 1977 "shortage" of arsenic acid manifested itself more strongly in the latter region.

The average annual acreage harvested prior to the freeze date for the period 1968-78 was 1.07 million acres (Table 15), or 0.33 million acres less than that implied by arsenic acid usage. Although this would appear to negate the hypothesis that acreage treated with harvest aid chemicals approximates acreage harvested prior to the freeze date, there are several factors which might account for this disparity:

1. Decreasing Dosage Rates--It has been alleged that in earlier years farmers tended to apply arsenic acid at relatively higher rates. In more recent times, factors such as increased treatment costs and educational efforts by extension agents have diminished the dosage of arsenic acid. Any current applications in excess of 0.375 gal/acre would tend to overstate estimates of treated acres that are based on arsenic acid sales volume.

2. Acre Treatments vs. Acres Treated--Arsenic acid is sometimes used in combination with defoliants (e.g., sodium chlorate) or other desiccants (e.g., paraquat). In addition, according to cotton production experts, when a rainfall immediately follows application, some growers resort to a second application. Neither of these factors was taken into account in the derivation of acres treated from the sales data.

3. Sales Information on Arsenic Acid--According to industry sources (Culver, 1980), approximately 20,000 to 30,000 gallons per year of arsenic acid are sold and used outside of Texas and Oklahoma. If the registered application dosage is assumed, then annual usage in Texas and Oklahoma has been overstated by approximately 53,000 to 80,000 acres.

4. Uncertainty Due to Weather--As illustrated in Table 15, the acreage actually harvested prior to the freeze date for the years 1968-78 was highly variable. To some extent, fluctuation in the freeze date is responsible, and can easily cause growers to estimate this date incorrectly. Another source of variation is the combined effect of the planting date, rainfall, and temperature during the growing season, all of which determine the date and uniformity of boll maturity. Finally, acreage harvested prior to the freeze date is partially a function of total acreage harvested, which is a function of both weather and economic variables.

5. Data Uncertainty--One of the key elements in this analysis is the harvest schedule, which permits the determination of the percentage of cotton harvested prior to the freeze date. The data for the harvest schedule is a product, not of surveys, but of an informal reporting system carried out by the extension service. No criticism of the extension service is intended; however, it is recognized that the expenditure of resources necessary for an accurate survey might well exceed the derived benefits. Under these circumstances the accuracy of the data is open to question.

The acreage where there is a potential need for a harvest aid chemical is defined as the base average. In the absence of any information to the contrary, it is assumed that the need for such a chemical is the same for both irrigated and dryland cotton. In view of the foregoing considerations, the assumption of equivalence between acreage harvested prior to the freeze date and acreage treated with a harvest aid chemical would seem to be a reasonable basis for estimating base acreage and subsequent weathering losses. Thus, base acreage for a given production region is established by multiplying the average acreage harvested by the mean percentage of

Table 15.--Total cotton acreage harvested and acreage harvested prior to the freeze date for the
Texas High and Rolling Plains and Oklahoma, 1968-78^a

	1978	1977	1976	1975	1974	1973	1972	1971	1970	1969	1968	Aggregated Average
<u>Northern High Plains</u>												
Cotton Acreage Harvested (1,000)	660	624	400	362	500	430	400	408	365	314	251	--
Acreage Harvested before Freeze Date (1,000)	99	175	0	51	0	90	4	0	0	9	30	--
Acreage Harvested before Freeze Date (percent)	15	28	0	14	0	21	1	0	0	3	12	--
<u>Southern High Plains</u>												
Cotton Acreage Harvested (1,000)	2,825	2,890	2,100	1,978	1,630	2,275	1,877	1,822	1,722	1,545	1,281	--
Acreage Harvested before Freeze Date (1,000)	1,017	1,850	504	297	359	956	56	383	413	247	346	--
Acreage Harvested before Freeze Date (percent)	36	64	24	15	22	42	3	21	24	16	27	--
<u>Northern Rolling Plains</u>												
Cotton Acreage Harvested (1,000)	700	725	570	456	441	520	449	424	393	447	381	--
Acreage Harvested before Freeze Date (1,000)	154	326	143	18	123	156	67	47	126	124	83	--
Acreage Harvested before Freeze Date (percent)	22	45	25	4	28	30	15	11	32	29	23	--

Table 15.--Total cotton acreage harvested and acreage harvested prior to the freeze date for the Texas High and Rolling Plains and Oklahoma, 1968-78^a--continued

	1978	1977	1976	1975	1974	1973	1972	1971	1970	1969	1968	Aggregated Average
<u>Southern Rolling Plains</u>												
Cotton Acreage Harvested (1,000)	620	611	480	424	434	550	547	510	543	528	442	--
Acreage Harvested before Freeze Date (1,000)	186	391	130	93	152	352	98	194	163	164	301	--
Acreage Harvested before Freeze Date (percent)	30	64	27	22	35	64	18	38	30	31	68	--
<u>Oklahoma</u>												
Cotton Acreage Harvested (1,000)	560	520	335	295	547	526	510	396	450	465	380	--
Acreage Harvested before Freeze Date (1,000)	123	234	84	12	153	158	77	44	144	135	87	--
Acreage Harvested before Freeze Date (percent)	22	45	25	4	28	30	15	11	32	29	23	--
Total Acreage Harvested before Freeze Date, All regions (1,000)	1,579	2,976	861	471	787	1,712	302	668	846	679	852	1,067

^a Sources: Acreage harvested from Texas crop and Livestock Rep. Serv., 1968-78 and Oklahoma Dept. of Agric., 1967-78.
Percent of acres harvested prior to the freeze date from Table 16.

acreage harvested prior to the mean freeze date.⁷ Based on the 90% confidence limits, an interval estimate of base acreage is derived in Table 16.

Unlike their counterparts in the Blacklands and Coastal regions, growers in the Texas Plains and Oklahoma have the option of waiting for frost to prepare cotton for stripper harvesting. Frost frequently terminates the growth of the cotton plant (Supak, 1978). Thus, in years when weather conditions favor early maturation, such as 1977, farmers tend to increase the use of chemical harvest aids. At the same time, the decision to treat is also a function of lint price, yield, etc. To the extent that a farmer makes a conscious economic decision not to treat, the grower can be said to rely upon the frost. Evidence of the reliance upon frost can be found in Table 12, wherein the percentage of acreage treated in Oklahoma and the Texas Plains in 1977 was substantially lower than in the Blacklands and Coastal Bend regions. Further confirmation of this practice is evident in the fact that most of the cotton acreage in the Texas Plains from 1968-78 was harvested after the "first hard-freeze date" (Table 17). The "first hard-freeze date" is the first autumn day when the temperature falls to 28° F or less. Due to certain physiological properties of the cotton plant, a hard freeze at 25° F or less is required to prepare it for mechanical stripping (Quisenberry, 1979). It should be noted, however, that the temperatures reported by the National Weather Service are typically measured at 4.5 to 5 ft. above the ground surface. Depending upon such factors as type and moisture content of the soil, the ground level temperature is generally 4 to 6° F colder than the level where temperature is normally recorded (Hildreth and Orton, 1963; and Orton, 1979). Therefore, it would be reasonable to assume a threshold of 28° F for the definition of a "first hard-freeze date" used in the analysis. As might be expected, the percentage of acreage harvested prior to the freeze date was greater in the Southern High and Rolling Plains than in the Northern High and Rolling Plains.

Although there is no information available for Oklahoma concerning the extent of pre-freeze harvest activity, it was found that the freeze pattern for the cotton-producing area of that State is nearly identical (Nov 20 vs. Nov. 18) to the adjacent Northern Rolling Plains of Texas. Thus, for the purposes of this analysis, estimates of pre-freeze harvest activity for the latter will serve as a proxy for Oklahoma.

Waiting for the frost to prepare cotton for stripper-harvesting is not, however, without potential yield/quality losses. Research over a 3-year period at Lubbock, Texas has shown that field weathering (i.e., lint deterioration starting from the day of boll maturity) results in reduced lint weight, darkening of the lint, shorter staple length, and decreased germination rate in the seed (Ray and Minton, 1973).

⁷ This approach ignores the use of paraquat for the following reasons: 1) there is no time series of data available by which usage patterns of paraquat can be inferred; and 2) although generally efficacious at low dosages, in some years, weather conditions are such that paraquat does not adequately prepare the cotton plant for stripper harvest (Supak, 1978). In view of these considerations, paraquat was not considered in this calculation.

Table 16.--Average pre-freeze cotton harvest time span and base acreage for irrigated and dryland cotton in the Texas Plains and Oklahoma^a

Parameter to be Estimated	Units	Cotton Production Regions				
		North High Plains	South High Plains	North Rolling Plains	South Rolling Plains	Oklahoma ^b
Pre-Freeze harvest time span	Days					
Low ^c		4 ^d	27	30	50	30
Intermediate ^e		13 ^d	36	38	55	38
High ^f		22 ^d	45	46	60	46
Acreage harvested before freeze	Percent					
Low ^c		4 ^d	18	18	29	18
Intermediate ^e		9 ^d	27	24	39	24
High ^f		14 ^d	36	30	49	30
Acreage harvested before freeze	Percent/day					
Low ^c		0.47	0.63	0.56	0.56	0.56
Intermediate ^e		0.69	0.75	0.63	0.71	0.63
High ^f		0.91	0.87	0.70	0.86	0.70
Dryland base ^g	1,000 acres					
Low ^c		6	282	114	170	82
Intermediate ^e		14	423	151	229	109
High ^f		21	563	189	288	136
Irrigated base ^h	1,000 acres					
Low ^c		20	233	15	8	NA
Intermediate ^e		44	349	20	11	NA
High ^f		69	465	25	14	NA

^a Sources: Mean values for pre-freeze harvest activity and percentage of acreage harvested prior to the freeze date from Table 17 mean values for dryland and irrigated acreage.

^b Parameters for Oklahoma are assumed to be the same for the Northern Rolling Plains in Texas. Actual acreage harvested, however, was used to calculate base acreage.

^c Average number of days of pre-freeze harvest activity minus one standard deviation times the t-value at the 90% confidence level for 10 degrees of freedom (i.e., $\bar{X} - S_{\bar{X}} \cdot t_{.90}$ for 10 d.f.).

^d Given the high degree of skewness in the underlying distributions (Table 17), caution is warranted on any inferences made from the resulting confidence limits.

^e Average number of days of pre-freeze harvest activity (i.e., \bar{X}).

^f $\bar{X} + S_{\bar{X}} \cdot t_{.90}$ for 10 d.f.

^g Average dryland acreage harvested x percent acreage harvested before freeze = non-irrigated base acreage.

^h Average irrigated acreage harvested x percent acreage harvested before freeze = irrigated base acreage.

Table 17.--Observed freeze data, days of pre-freeze harvest activity, percentage of cotton acreage harvested before the freeze date for various regions of Texas, 1968-78^a

	Northern High Plains			Southern High Plains			Northern Rolling Plains			Southern Rolling Plains		
	Observed Freeze Date ^b	Pre-Freeze Harvest Activity	Cotton Acreage Harvested before Freeze Date ^c	Observed Freeze Date ^b	Pre-Freeze Harvest Activity	Cotton Acreage Harvested before Freeze Date ^c	Observed Freeze Date ^b	Pre-Freeze Harvest Activity	Cotton Acreage Harvested before Freeze Date ^c	Observed Freeze Date ^b	Pre-Freeze Harvest Activity	Cotton Acreage Harvested before Freeze Date ^c
		Days	Percent		Days	Percent		Days	Percent		Days	Percent
1978	11/14	34	15	11/28	60	36	12/2	43	22	12/3	52	30
1977	11/2	51	28	11/10	56	64	11/10	56	45	11/10	56	64
1976	10/8	0	0	11/12	33	24	11/12	38	25	11/12	43	27
1975	11/10	14	14	11/13	15	15	11/10	6	4	11/13	42	22
1974	11/12	0	0	11/14	45	22	11/30	53	28	11/29	60	35
1973	11/20	25	21	11/27	39	42	11/28	43	30	12/5	57	64
1972	10/30	2	1	11/14	4	3	11/20	31	15	11/20	51	18
1971	11/6	0	0	11/19	35	21	11/7	23	11	12/18	64	38
1970	10/9	0	0	10/28	39	24	11/15	37	32	11/3	44	30
1969	10/13	3	3	10/13	33	16	11/19	54	29	11/19	70	31
1968	11/11	17	12	11/11	42	27	11/11	37	23	11/28	61	68
Average	11/2 ^c	13	9	11/11 ^d	36	27	11/18 ^d	38	24	11/23 ^d	55	39

^a The weather stations from which the data have been taken are as follows: Northern High Plains--Amarillo; Southern High Plains--Lubbock; Northern Rolling Plains--Childress; Southern Rolling Plains--Abilene.

^b Observed Freeze Date: The first autumn day when the temperature falls to 28° F or less, from National Oceanic Atmos. Admin., 1968-78.

^c Interpreted from data in bar chart format (Texas Crop and Livestock Rep. Serv., 1968-78).

^d Although temperature data are available for 1948-78, harvest activity data are available only for the years 1968-78. It should be noted, however, that the means calculated for the 31-year period differ little from those for the 11-year period (± 2 days for a given region).

Based on the findings of Ray and Minton (1973), the following potential lint weight losses in percentage terms have been estimated:

- 0.43% per day for the period 1-7 days following boll maturity;
- 0.24% per day for the period 8-28 days following boll maturity;
- 0.08% per day for the period 29-77 days following boll maturity;

Lint can be expected to darken after the first 3 weeks following boll maturity, such that its grade decreases from white middling to white strict low middling by the end of 8 weeks. By the end of 12 weeks, the lint grade will have further deteriorated to white low middling. According to USDA's 1979 cotton grading schedule (USDA, 1979b), the decrease from middling to strict low middling implies a loss of 165 basis points, and from strict low middling to low middling, a loss of 280. Therefore, if lint is left in the field 12 weeks following boll maturity, the cumulative loss would be 445 basis points, or 4.45cents/pound of lint. The base grade for purposes of calculating premiums and discounts is presently white strict low middling with a staple length of 1-1/16 inches.

Staple length can be expected to diminish by 1/32 inch with exposure of 6 to 7 weeks or more. This decrease implies the loss of 155, 150, and 115 basis points for cotton graded as middling, strict low middling, and low middling, respectively.

Finally, seed germination might decrease by 2.5% per week (Ray and Minton, 1973); however, the economic consequences of such effects can not be estimated in any meaningful manner. Given that only about 2.5% of the cottonseed harvested is used for replanting (8 pounds planted/acre \times 100 \div 320 pounds yield/acre = 2.5%; Brints, 1979), it would appear that the economic impact of such losses is limited. Although seed deterioration can also lower the resulting oil quality, this effect was not investigated by Ray and Minton (1973). Reductions in the germination rate would not reduce oil quality significantly when it is designated for crushing. Understating the losses for field weathering and effects on seed quality will be ignored in the analysis.

It should be noted, however, that chemical treatment is also not without potential risks. In an effort to hasten maturity of the 1979 crop, many Texas Plains cotton growers used a chemical desiccant/defoliant, instead of waiting for the frost. The physiological reaction of the plants to this treatment is not precisely understood; however, the maturing crop's growth was stunted. As a consequence, the micro-naire for Texas plains cotton in 1979 was considerably below average (Cotton Grower, 1980).

Lint quality declines with time after the boll opens and harvest occurs. To determine the number of days that the lint might be exposed to weathering, the average time span of harvest activity between crop maturity and the observed freeze dates for the period 1968-78 was estimated (Table 17). In the absence of any knowledge of the cumulative frequency distribution of acreage harvested prior to the freeze date, a simple averaging procedure of dividing the mean percentage of cotton acreage harvested prior to the freeze date by the mean number of pre-freeze harvest days is used (Table 17). For example, in the Northern High Plains, the average acreage harvested prior to the freeze date is 0.69% per day (Table 16).

As explained previously, there are three components of potential weathering losses: reduced lint weight, stated as a percentage reduction of the normal lint yield; reduced staple length; and lint darkening. Reduced staple length and lint

darkening are measured in cents per pound. To continue with the previous example, annual weathering losses for the Northern High Plains can be calculated as follows:

$$\text{Weather Losses} = [13 \text{ days} \times 0.69\% \times \text{average acreage harvested} \times \text{average daily percentage of lint weight reduction} \times \text{average lint yield} \times \text{average lint price}] + [(\text{reduced staple length} + \text{lint darkening factor}) (\text{average lint yield} \times \text{base acres})].$$

The prices and technical parameters to be used for the impact analysis are detailed below:

--Cotton yields: For Oklahoma, only a Statewide total is available for both irrigated and dryland yields. Because no trend is evident, a 1967-78 average of 291 pounds lint/acre is used (Oklahoma Dept. Agric., 1967-78; and USDA, 1979b).

For Texas, data are available for the High and Rolling Plains by crop reporting district. Inasmuch as there was a slight negative trend apparent in the years 1967-78, an average yield for the period 1974-78 is used (Table 18). Harvest-aid treatment costs given in Table 13) are \$2.5/acre for arsenic acid plus either \$2.25/acre or \$2.00/acre for aerial or ground application, respectively.

In recent years there has been a sharp upward trend in overall cotton acreage in the Texas Plains (Texas Crop and Livestock Rep. Serv. 1968-78a; and USDA, 1979b). Hence, only 1977 and 1978 will be used for the calculation of average acreage (Table 19). No such trend is evident in Oklahoma; consequently, an average for the period 1967-78 will be used--namely, 448,000 acres.

Table 18.--Average yields of lint for 1974-78

Crop Reporting District	Lint Yield	
	Dryland	Irrigated
	- - - - - Pounds/Acre - - - - -	
Northern High Plains	223	376
Southern High Plains	249	383
Northern Rolling Plains	263	413
Southern Rolling Plains	291	429

Table 19.--Average cotton acreage harvested for the years 1977-78 by crop reporting district

	Dryland	Irrigated	Total
	- - - - - 1,000 Acres - - - - -		
Northern High Plains	152	490	642
Southern High Plains	1,565	1,293	2,858
Northern Rolling Plains	631	82	713
Southern Rolling Plains	587	29	448
Oklahoma	NA	NA	NA

State average prices for the years 1977 and 1978 of 51.9 and 50.3 cents/pound of lint for the Texas Plains and Oklahoma respectively, will be used for calculating lint impacts.

Impacts of Arsenic Acid Cancellation

Blacklands.--By varying the acreage for which there is a total loss of output, a range of potential impacts is generated (Table 20). Thus a 25% change in the acreage (on which production is totally lost) in either direction from the assumed intermediate level (i.e., 190,400 acres) results in approximately a 19% change in the aggregate dollar impact. Given the sensitivity of the results to change in production losses, combined with the general uncertainty surrounding the assumptions upon which the intermediate level impacts are based, there is potential for substantial error in the estimated impacts. The calculations of the impacts are as follows:

Calculation of High Level Impacts

- A. Only 40% of acreage can be successfully stripped. The increased desiccant treatment costs are \$7.53/acre.

$$a. \quad 0.4 \times 476,000 \text{ acres} \times \$7.53/\text{acre} \dots\dots\dots \$1,433,712$$

- B. 50% of acreage cannot be ginned. This effects three cost/revenue changes: (a) increased treatment costs; (b) total loss of lint and seed net revenue on affected acreage; (c) elimination of stripping, ginning, and associated marketing charges. Thus:

$$a. \quad 0.5 \times 476,000 \text{ acres} \times \$7.53/\text{acre} \dots\dots\dots \$1,792,140$$

$$b. \quad [(\$0.519/\text{pound lint} \times 225 \text{ pounds lint/acre})$$

$$+ (365.6 \text{ pounds seed/acre} \times \$0.04388/\text{pound})]$$

$$\times 238,000 \dots\dots\dots \$31,610,684$$

c. $(\$4.64/\text{bale} + \$25/\text{bale} + \$45.61/\text{bale})$

$\times (225 \text{ pounds/acre} \div 480 \text{ pounds/bale}) \times 238,000 \dots \$8,395,078$

d. Total = a + b - c $\dots \$25,007,746$

C. 10% of acreage can be picked with: (a) increased treatment costs; (b) a lint and seed yield loss of 25%; (c) increased harvest costs of \$20/bale.

a. $0.1 \times 476,000 \times \$7.53 \dots \$358,428$

b. $[(\$0.519 \times 225 \times 0.25) + (365.5 \times 0.25 \times \$0.4358)]$

$\times 0.1 \times 476,000 \dots \$1,580,528$

c. $(\$45 - \$25) \times (225 \div 480) \times 47,600 \dots \$446,250$

d. Total = a + b + c $\dots \$2,385,206$

D. Total A + B + C High Level Impact $\dots \$28,826,664$

Calculation of Intermediate Level Impacts

A. Only 50% of acreage can be successfully stripped and \$7.53/acre for increased desiccant treatment costs. Thus:

a. $0.5 \times 476,000 \times \$7.53 \dots \$1,792,141$

B. 40% of acreage cannot be ginned, thus effecting net revenue changes as in the High Level Impacts above:

a. $0.4 \times 476,000 \times \$7.53 \dots \$1,433,712$

b. $[(\$0.519 \times 225) + (365.6 \times \$0.04388)]$

$\times 190,400 \dots \$25,288,547$

c. $(\$4.64 + \$25 + \$45.61) \times (225 \div 480) \times 190,000 \dots \$6,716,063$

d. Total = a + b - c $\dots \$20,006,196$

C. Same as for High Level Impacts. $\dots \$2,385,206$

D. A + B + C Intermediate Level Impacts. $\dots \$24,183,542$

Calculations of Low Level Impacts

A. Only 60% of acreage can be successfully stripped and \$7.53/acre for increased desiccant treatment costs.

a. $0.6 \times 476,000 \times \$7.53 \dots \$2,150,568$

- B. 30% of acreage cannot be ginned, effecting net revenue changes as in the High and Intermediate Level Impacts above:
- a. $0.3 \times 476,000 \times \7.53 \$1,075,284
 - b. $[(\$0.519 \times 225) + (365.6 \times \$0.04388)]$
 $\times 142,800$ \$18,966,343
 - c. $(\$4.64 + \$25 + \$45.61) \times (225 \div 480) \times 142,800$ \$5,037,047
 - d. Total = a + b - c \$15,004,580
- C. Same as for High and Intermediate Level Impacts \$2,385,206
- D. A + B + C Low Level Impacts \$19,540,354

Table 20.--Estimated impacts of arsenic acid cancellation to growers in the Blacklands

Impact Level	Acreage with Total Production Loss ^a	Change in Acreage from Intermediate Level	Impacts	Change in Impacts from Intermediate Level
	Acres	Percent	Million Dollars	Percent
High	238,000	+25	28.8	+19.0
Intermediate	190,400	--	24.2	--
Low	142,800	-25	19.5	-19.4

^a Derived by multiplying 476,000 acres by 0.50, 0.40, and 0.30.

The 1979 Upland Cotton Program authorizes disaster payments for yield losses caused by events beyond the producers' control (Cunningham, 1980), and therefore cotton growers will not sustain the full losses shown in Table 20. The disaster payment (DP) to a given farmer is a function of the disaster payment rate (DPR) (which is set at 1/3 the annually established target price (TP), and the farm payment yield (FPY). The latter is the average yield on harvested acreage over the previous 3-year period. Finally, disaster payments are made only for production losses below 75% of the farm payment yield on planted acreage for the year in question. Thus, for such acres, the disaster payment (on a per-acre basis) is: $DP = 0.75 \times DPR \times FPY$ (USDA, 1979).

To determine the aggregate disaster payment (in the event of the cancellation of arsenic acid), the per-acre payment must be multiplied by the number of acres on which production is lost. Farm payment yield is based on a 206 pounds/acre yield, the average for the Blackland region for the years 1974-1976; the payment rate is estimated at 16.66 cents/pound based on a target price of 49.9 cents/pound.

As shown in Table 21, the resulting disaster payments range from 3.7 to \$6.1 million, depending upon the assumptions made concerning the acreage on which cotton production is totally lost. These payments are then subtracted from the impacts shown in Table 20 to arrive at net financial impacts to the grower as a result of the cancellation of arsenic acid. These net impacts are 22.7, 19.3, and \$15.8 million for the high, intermediate, and low impact levels, respectively. These payments would decline over time, however, as the losses become part of the base period, and eventually would be eliminated.

Finally, it should be noted that some growers are also covered by crop insurance written with the Federal Crop Insurance Corp. (FCIC, 1979). In addition to the disaster payments authorized under the 1977 Act, growers covered by crop insurance would receive indemnities on 65% of average yield at a payment rate approximately equal to market prices. It should be noted, however, that use of FCIC insurance by Blacklands farmers has been steadily declining in recent years--from 69,168 acres in 1968 to 16,000 acres in 1978 (FCIC, 1979). Moreover, acreage insured as a percentage of acreage planted has declined from 9.5% in 1968 to 1.3% in 1978. If the present trend continues, it is reasonable to expect that the acreage covered by FCIC insurance will become negligible and, for this reason, inclusion of any potential indemnities is ignored in the present analysis.

Table 21.--Estimated impacts of arsenic acid cancellation to growers in the Blacklands receiving disaster payments

Impact Level	Gross Impacts ^a	Disaster Payment	Disaster Payments ^b	Net Impacts
	<u>Million Dollars</u>	<u>1,000 Acres</u>	- - <u>Million Dollars</u> - - -	
High	28.8	238.0	6.1	22.7
Intermediate	24.2	190.4	4.9	19.3
Low	19.5	142.8	3.7	15.8

^a See Table 20.

^b Derivation: Aggregate disaster payment = 0.75 x 206 pounds/acre x \$0.166/pound x affected acreage.

Coastal Regions.--The impact for this region will be approximated by a minimum partial budget estimate using assumptions discussed previously in this chapter. A maximum partial budget estimate is also made. The two estimates provide the extremes for the likely true impact of arsenic acid cancellation.

The total increase in treatment costs from the minimum partial budget estimate is approximately \$2.2 million (\$7.74 increased cost per acre from Table 13 times 291,000 acres treated). As stated above, this estimate is based on the assumption that the alternative, paraquat, is equally effective.

The maximum economic impact of a loss of arsenic acid would be approximately \$9.3 million the first year after a potential cancellation, increasing to \$15.2 million the second year and decreasing to \$14.3 million in subsequent years (Table 22).

The increased impact in the second year would be due to increased insect control costs on all acres and to yield reductions on stripped acres because of reduced insect control without short-season cotton. The loss of net revenues could decrease in subsequent years when the Coastal Bend producers obtain an adequate number of pickers.

Table 22.--Maximum partial budget impact of canceling arsenic acid use in the Coastal Bend and Lower Valley regions of Texas

Region/ Harvest Technique	Acres treated ^b	Decrease in Net Revenues ^a			Per-Acre Impact for Subsequent Years
		First Year	Second Year	Subsequent Years	
		- - - - -	<u>1,000 Dollars</u>	- - - - -	<u>Dollars</u>
Coastal Bend					
Picked	127,500	6,740.9	7,564.6	6,677.2	
Stripped	42,500	328.9	1,919.7	1,919.7	
Regional Total	170,000	7,069.8	9,484.3	8,596.9	50.57
Lower Valley					
Picked	90,750	2,037.3	4,442.2	4,442.2	
Stripped	30,250	234.1	1,262.9	1,262.9	
Region Total	121,000	2,271.4	5,705.1	5,705.1	47.15
Total	291,000	9,341.2	15,189.4	14,302.0	

^a Acres treated times respective decrease in net returns per acre from Tables 23 and 24.

^b Total acres treated from unpublished survey on cotton pesticide usage conducted for USDA in 1977. Portion in each region and portion harvested with each technique estimated by Assessment Team.

Table 23.--Maximum partial budget impact of canceling arsenic acid use in the Coastal Bend region of Texas

Harvest Technique and Item	Decrease in Net Revenue		
	First Year	Second Year	Subsequent Year
	----- Dollars/Acre -----		
Picked acreage			
Treatment costs			
Harvest aid ^a	7.74	7.74	7.74
Insect control ^b	--	19.60	19.60
Sub-total	7.74	27.34	27.34
Harvest costs ^c	--	15.50	15.50
Gin, bag, ties ^c	-24.78 ^d	-16.26 ^d	-16.26 ^d
Yield loss ^e	64.49	25.79	25.79
Quality loss ^f	5.42	6.96	--
Total	52.87	59.33	52.37
Stripped acreage			
Treatment costs			
Harvest aid ^a	7.74	7.74	7.74
Insect control ^b	--	19.60	19.60
Sub-total	7.74	27.34	27.34
Harvest costs ^c	--	-2.50 ^d	-2.50 ^d
Gin, bag, ties ^c	--	-5.46 ^d	-5.46 ^d
Yield loss ^e	--	25.79	25.79
Quality loss	--	--	--
Total	7.74	45.17	45.17

^a Table 13.

^b Assessment Team provided this estimate based on expected increased insect pressures due to longer season with paraquat as the harvest aid.

^c Calculated from FEDS Budgets (1977) as decreased processing cost at the gin due to yield reduction.

^d Negative values represent increases.

^e \$64.49 = 124.2 (25% of yield of 497 pounds per acre) x \$0.519 (price in dollars received for cotton). \$25.79 = 49.7 (10% of yield of 497 pounds per acre) x \$0.519 (price in dollars received per pound of cotton). (Texas Crop and Livestock Rep. Serv., 1978).

^f \$5.42 = 347.9 (yield after 70% yield loss) x 0.03 (3% yield loss) x \$0.519 (price in dollars received for cotton). 6.69 = 447.3 (yield after 10% yield loss) x 0.03 (3% yield loss) x \$0.519 (price in dollars received per pound of cotton).

Table 24. Maximum partial budget impact of canceling arsenic acid use in the Lower Valley region of Texas

Harvest Technique and Item	Decrease in Net Revenue		
	First Year	Second Year	Subsequent Year
	<u>Dollars/Acre</u>		
Picked acreage			
Treatment costs			
Harvest aid ^a	7.74	7.74	7.74
Insect Control ^b	--	19.60	19.60
Sub-total	7.74	27.34	27.34
Harvest costs ^a	20.00	15.50	15.50
Gin, bag, ties ^c	-12.00 ^d	-16.26 ^d	-16.26 ^d
Yield loss ^e	--	22.37	22.37
Quality loss ^f	6.71	--	--
Total	22.45	48.95	48.95
Stripped acreage			
Treatment costs			
Harvest aid ^a	7.74	7.74	7.74
Insect control ^b	--	19.60	19.60
Sub-total	7.74	27.34	27.34
Harvest costs ^c	--	-2.50 ^d	-2.50 ^d
Gin, bag, ties ^c	--	-5.46 ^d	-5.46 ^d
Yield loss ^e	--	22.37	22.37
Total	7.74	41.75	41.75

^a Table 13.

^b Assessment Team provided this estimate based on expected increased insect pressures due to a longer growing season with paraquat as the harvest aid.

^c Calculated from FEDS Budgets (1977) as decreased processing cost at the gin due to yield reduction.

^d Negative values represent increases.

^e \$22.37 = 43.1 (10% of 431 pound per acre cotton yield) x \$0.519 (price in dollars received per pound of cotton).

^f \$6.71 = 43.1 (3% yield loss) x \$0.519 (price in dollars received per pound of cotton).

The total impact in subsequent years would be \$8.6 million in the Coastal Bend region and \$5.7 million in the Lower Valley. The per-acre impacts in subsequent years would be \$50.57 in the Coastal Bend region and \$47.15 in the Lower Valley.

Texas Plains and Oklahoma.--Weathering losses are sustained in terms of both lint quantity and quality. Quality losses, stated as average daily percentage reductions in lint yield, are shown in Table 25. Shown in the same table are the estimated per-pound losses due to degradation of quality. Only in the Southern Rolling Plains, where the cotton lint matures early in relation to the mean freeze date, are quality losses significant.

Use of the foregoing loss parameters permits the calculation of the economic losses due to weathering, the results of which are presented in Tables 26 and 27. In the Southern Rolling Plains, where exposure to weathering effects is the longest (i.e., the most number of pre-freeze harvest days Table 25), potential weathering losses are the greatest.

When arsenic acid treatment cost savings are subtracted from weathering losses, the remainder represents the net financial impact to growers resulting from the cancellation of arsenic acid (Table 27). The annual net impact to growers ranges from 2.22 to \$12.95 million in the aggregate (i.e., Texas plus Oklahoma) and from 2.40 to \$7.35 on a per-acre basis.

At the price/yield levels used in the analysis, it may be economically irrational for growers in the Northern High Plains to treat with a harvest aid chemical, which is consistent with a contention of the Texas Agric. Ext. Serv. (Supak and Metzger, undated); however, at the high range of the estimated impact, chemical treatment is financially justified. Moreover, were it possible to measure the growers' risk preferences, and given the extreme variability of the weather-related parameters which determine the ranges of the estimated impacts, use of a harvest aid chemical may well be economically rational in all regions.

Limitations of the Analysis

Blacklands.--There are two critical limitations to the foregoing analysis: 1) the lack of sufficient data to quantify the expected yield/quality loss as a result of arsenic acid cancellation; and 2) use of the partial budget framework, wherein no adjustments by economic agents are permitted. Although there is little doubt that the most widely used alternative (i.e., paraquat) does not perform as reliably as arsenic acid, this differential performance has yet to be accurately measured. Moreover, in view of the highly variable performance of paraquat across localities, it is unlikely that any meaningful test-plot data will be forthcoming in the near future.

Coastal Regions.--This study has limitations regarding the magnitude of the impacts of a cancellation of arsenic acid use.

1. The agricultural scientists experienced with cotton production in this region could only place reasonable limits on the magnitude of expected yield impacts.
2. Additional pickers may not be available to enable two pickings per year.

Table 25.--Cotton weathering losses for the Texas Plains and Oklahoma

Cotton Production Region	Pre-freeze Harvest Time Span ^a	Quality Losses ^b			Value of Quality Losses ^c	Quantity Losses	
		Lint Darkening	Staple Length Reduc- tion	Total		Lint Weight Reduction Factor ^d	
	<u>Days</u>	- - - <u>Basis Points</u> - - -			<u>Cents/ Pound</u>	<u>Percent Yield Loss Per Day</u>	
Northern High Plains							
Low	4	--	--	--	--	1.72	
Intermediate	13	--	--	--	--	0.34	
High	22	--	--	--	--	0.30	
Southern High Plains							
Low	27	--	--	--	--	0.29	
Intermediate	36	--	--	--	--	0.24	
High	45	--	155	155	1.55	0.21	
Northern Rolling Plains							
Low	30	--	--	--	--	0.27	
Intermediate	38	--	--	--	--	0.23	
High	46	--	155	155	1.55	0.14	
Southern Rolling Plains							
Low	50	--	155	155	1.55	0.13	
Intermediate	55	--	155	155	1.55	0.11	
High	60	165	155	320	3.20	0.09	
Oklahoma							
Low	30	--	--	--	--	0.27	
Intermediate	38	--	--	--	--	0.23	
High	46	--	155	155	1.55	0.14	

^a See Table 16.^b The decision framework for assigning basis points is as follows:

(1) Let X = the number of pre-freeze harvest days (i.e., lint exposure time)

--If X ≤ 56, then assign white middling

--If 56 < X ≤ 84, then assign white strict middling (WM - WSM = 165 basis points)

--If X > 84, then assign white low middling (WSM - WLM = 280 basis points).

(2) Reduction of staple length by 1/32 inch for white middling implies reduction of 155 basis points.

^c 100 basis points = 1 cent per pound of lint.^d Lint weight reduction as a function of lint exposure following boll maturity. To take an example, the high lint weight reduction factor for the Southern High Plains is calculated as follows:

$$[(0.0043 \times 7) + (0.0024 \times 21) + (0.0008 \times 17)] = 0.00209$$

Table 26.--Estimated cotton weathering losses for the Texas Plains and Oklahoma

Cotton Producing Regions	$\left[\sum_{i=1}^n \text{Days}^a \times \text{Harvested Per Day Before Freeze} \times \text{Average Acreage Harvested}^b \times \text{Daily Yield Loss}^a \times \text{Average Lint Yield}^c \times \text{Average Lint Price}^d \right]$	$+ \left[\text{Value of Quality Losses}^d \times \text{Average Lint Yield}^c \times \text{Base Acres}^a \right]$	= Weathering Losses							
	<u>Days</u>	<u>Percent of Acreage</u>	<u>1,000 Acres</u>	<u>Factor Percent</u>	<u>Pounds Per Acre</u>	<u>Dollars Per Pound</u>	<u>Dollars Per Pound</u>	<u>Pounds Per Acre</u>	<u>1,000 Acres</u>	<u>1,000 Dollars</u>
Northern High Plains (irrigated)										
Low	4	0.47	490	1.72	376	0.519	--	376	20	77.30
Intermediate	13	0.69	490	0.34	376	0.519	--	376	44	204.14
High	22	0.91	490	0.30	376	0.519	--	376	69	660.44
Northern High Plains (dryland)										
Low	4	0.47	152	1.72	223	0.519	--	223	16	14.22
Intermediate	13	0.69	152	0.34	223	0.519	--	223	14	37.56
High	22	0.91	152	0.30	223	0.519	--	223	21	121.51
Southern High Plains (irrigated)										
Low	27	0.63	1,293	0.29	383	0.519	--	383	233	1,774.99
Intermediate	36	0.75	1,293	0.24	383	0.519	--	383	349	3,081.14
High	45	0.87	1,293	0.21	383	0.519	0.0155	383	465	7,620.55
Southern High Plains (dryland)										
Low	27	0.63	1,565	0.29	249	0.519	--	249	282	1,396.73
Intermediate	36	0.75	1,565	0.24	249	0.519	--	249	423	2,424.53
High	45	0.87	1,565	0.21	249	0.519	0.0155	249	563	5,997.27
Northern Rolling Plains (irrigated)										
Low	30	0.56	82	0.27	413	0.519	--	413	15	123.58
Intermediate	38	0.63	82	0.23	413	0.519	--	413	20	188.72
High	46	0.70	82	0.14	413	0.519	0.055	413	25	346.24
Northern Rolling Plains (dryland)										
Low	30	0.56	631	0.27	263	0.519	--	263	114	605.56
Intermediate	38	0.63	631	0.23	263	0.519	--	263	151	924.78
High	46	0.70	631	0.14	263	0.519	0.0155	263	189	1,682.90

Table 26.--Estimated cotton weathering losses for the Texas Plains and Oklahoma--continued

Cotton Producing Regions	$\left[\sum_{i=1}^n \text{Days}^a \right]$ where $n =$	\times	Harvested Per Day Before Freeze	\times	Average Acreage Harvested ^b	\times	Daily Yield Loss ^a	\times	Average Lint Yield ^c	\times	Average Lint ^d Price	$+$	$\left[\text{Value ofQualityLosses}^d \times \text{AverageLintYield}^c \times \text{BaseAcres}^a \right]$	$=$	Weathering Losses				
	<u>Days</u>		<u>Percent of Acreage</u>		<u>1,000 Acres</u>		<u>Factor Percent</u>		<u>Pounds Per Acre</u>		<u>Dollars Per Pound</u>		<u>Dollars Per Pound</u>		<u>Pounds Per Acre</u>		<u>1,000 Acres</u>		<u>1,000 Dollars</u>
Southern Rolling Plains (irrigated)																			
Low	50		0.56		29		0.13		429		0.519		0.0155		429		8		113.13
Intermediate	55		0.71		29		0.11		429		0.519		0.0155		429		11		150.80
High	60		0.86		29		0.09		429		0.519		0.0155		429		14		184.55
Southern Rolling Plains (dryland)																			
Low	50		0.56		587		0.13		291		0.519		0.0155		291		162		1,677.40
Intermediate	55		0.71		587		0.11		291		0.519		0.0155		291		217		2,217.10
High	60		0.86		587		0.09		291		0.519		0.0155		291		280		2,700.60
Oklahoma (dryland plus irrigated)																			
Low	30		0.56		448		0.27		291		0.503	--			291		82		461.05
Intermediate	38		0.63		448		0.23		291		0.503	--			291		109		704.09
High	46		0.70		448		0.14		291		0.503	0.0155			291		136		1,308.12

^a Tables 16 and 25.^b Table 19.^c Table 18.^d Page 73.

Table 27.--Weathering losses, foregone treatment costs, and total financial impacts to cotton growers resulting from the cancellation of arsenic acid in the Texas Plains and Oklahoma

Cotton Producing Region	Total Base Acres	Weathering Losses ^a	Foregone Treatment Costs with Arsenic Acid	Aggregate Net Impact to Growers	Net Impact
	1,000	- - - - -	1,000 Dollars	- - - - -	Dollars/ Acre
Texas					
Northern High Plains					
Low	26	91.5	113.9 ^b	(22.4)	(0.86)
Intermediate	58	241.7	254.0 ^b	(12.3)	(0.21)
High	90	781.9	394.2 ^b	387.7	4.31
Southern High Plains					
Low	515	3,171.7	2,255.7 ^b	916.0	1.78
Intermediate	772	5,505.7	3,381.4 ^b	2,124.3	2.75
High	1,028	13,617.8	4,502.6 ^b	9,115.2	8.87
Northern Rolling Plains					
Low	129	729.1	561.2 ^c	167.9	1.30
Intermediate	71	1,113.5	743.9 ^c	369.6	2.16
High	214	2,029.1	930.9 ^c	1,098.2	5.13
Southern Rolling Plains					
Low	170	1,790.5	739.5 ^c	1,051.0	6.18
Intermediate	229	2,369.9	996.2 ^c	1,371.7	5.99
High	288	2,885.2	1,252.8 ^c	1,632.4	5.67
Oklahoma					
Low	82	461.0	356.7 ^c	104.3	1.27
Intermediate	109	704.1	474.2 ^c	229.9	2.11
High	136	1,308.1	591.6 ^c	716.5	5.27
Texas and Oklahoma					
Low	922	6,243.8	4,027.0	2,216.8	2.40
Intermediate	1,338	9,932.9	5,849.7	4,083.2	3.05
High	1,762	20,622.1	7,672.1	12,950.0	7.35

^a Table 26.

^b Derivation: \$2.25 cost of arsenic acid + \$2.13 application cost = \$4.38/acre. The per-acre application cost is a weighted average, with the weights reflecting the respective percentage for ground and aerial application. Cost of ground application: \$2.00/acre. Cost of aerial application: \$2.25/acre. Thus: $[(\$2.00 \times 0.51) + (\$2.25 \times 0.49)] = \$2.13/\text{acre}$. The total treatment cost is the product of per acre treatment cost times base acres.

^c Derivation: \$2.25 cost of arsenic acid + \$2.10 application cost = \$4.35/acre. As calculated in footnote b, the per-acre application cost is: $[(\$2.00 \times 0.62) + (\$2.25 \times 0.38)] = \$2.10/\text{acre}$. The total treatment cost is the product of per-acre treatment cost times base acres.

3. The maximum impact assumption was based on the expectation that pickers and strippers had sufficient mobility to harvest all acres dried adequately for strippers or pickers.
4. Acres treated with arsenic acid in 1977 were typical of current arsenic acid use.

Texas Plains and Oklahoma.--In the discussion which follows, the limitations of the impact analysis for the Texas Plains and Oklahoma are identified, and an attempt is made to predict the resulting direction of bias.

1. Exclusion of paraquat from the impact analysis: Although currently used by many growers in the Texas Plains and Oklahoma, paraquat was not considered as an alternative in the impact analysis for the following reasons: First, there are no data to ascertain the percentage of growers in the Texas Plains and Oklahoma who normally treat with paraquat. More importantly, the issue of comparative efficacy (paraquat vs. arsenic acid) has not yet been resolved.

In view of these considerations, the benefits of arsenic acid were calculated on the assumption that frost action is the only alternative. This approach will somewhat overstate the impacts to cotton growers.

2. Aggregated data: Whereas meteorological data are available at the local level (i.e., individual weather stations), information on the timing of the cotton harvest is available only at the relatively aggregated level of Federal crop reporting districts. Given that these districts each comprise several counties, some analytical distortion may be introduced when local weather conditions are assumed to be representative of district-wide conditions.

It would appear that this procedure will understate the impact of cancellation in the Southern High Plains. The Lubbock area, which represents the heartland of cotton production in the Texas Plains, is located near the northern extremity of the Southern High Plains, a crop reporting district some 150 miles long in a north-south direction.

In the absence of more comprehensive data on local weather conditions over time, it is not possible to predict the direction of bias in the remaining crop reporting districts in Texas and Oklahoma.

3. Insufficient time series data: For weather and weather-related variables (e.g., acreage harvested before the freeze), a relatively long time series of data (i.e., greater than 20 years) is statistically preferable. With the exception of temperature, all other weather-related variables were estimated with only 11 years of data. The direction of any resulting bias is in this instance unknown.

4. Calculation of weathering losses: The weathering loss parameters were derived from a study by Ray and Minton (1973). This study was based upon only 3 years of data; in some cases, the estimated losses were statistically insignificant. Thus, use of these results in the calculation of weathering losses leads to uncertainty in the estimate of the impact of cancellation.

5. Exclusion of yield and price variation from the analysis: The growers' decision to treat with a harvest aid chemical is based upon the expectation of improving net revenues. Although the analysis assumed constant yields and prices, inclusion of yield/price variation would not have altered the intermediate estimate of grower impacts; however, the range would have been widened considerably.

Summary of Economic Impact Analysis of Canceling Arsenic Acid

Arsenic Acid—Cotton Desiccant

- A. USE: Primarily in Texas and Oklahoma by producers who stripper-harvest cotton.
- B. SITES: Aerial and ground application on stripper-harvested cotton.
- C. SPECIFICATION: Desiccation of leaves and terminals, resulting in death of cotton plant in preparation for stripper harvesting.

D. ALTERNATIVES:

Chemical desiccants: Paraquat.

Non-chemical controls: Killing frost (28° F or less).

Comparative efficacy: Expert opinion has it that paraquat is less efficacious than arsenic acid. Frost is equally efficacious, but is sufficiently reliable in only the Texas Plains and Oklahoma. Quality losses may result from reliance upon frost.

Comparative costs:

Desiccant	Region		
	Coastal	Blacklands	Texas Plains and Oklahoma
	- - - - - Dollars/Acre - - - - -		
Arsenic Acid	2.25	2.25	2.25
Paraquat	5.00	1.50	10.00
Frost	NA	NA	0

Aerial application costs are \$0.25 per acre less for paraquat than for arsenic acid due to the latter's corrosive action. Ground application costs are the same for both chemicals.

E. EXTENT OF USE:

An average of 2.2 million acres treated annually (any variation depending primarily upon rainfall and temperature conditions), which represents 15% of U.S. upland cotton acreage. Use is stable in Coastal and Blacklands regions; highly variable in Texas Plains and Oklahoma.

F. ECONOMIC IMPACTS:

<u>User:</u>	<u>Region</u>	<u>Impacts</u>
		<u>Million Dollars</u>
	Blacklands	15.8 to 22.7
	Coastal	2.3 to 14.3
	Texas Plains and Oklahoma	2.2 to 13.0
	Total	20.3 to 50.0
<u>Consumer:</u>	Not estimated	

G. SOCIAL/COMMUNITY IMPACTS: Due to potential shifts from cotton to sorghum, the existing trend of gin closures in the Blacklands may be greatly exacerbated.

H. LIMITATIONS OF THE ANALYSIS: Partial budget techniques were used to estimate impacts. Comparative efficacy for paraquat vs. arsenic acid is unknown. Limitations specific to each region can be found at the conclusion of the analysis for the respective region.

I. ANALYSTS AND DATE: William A. Quinby and Robert Torla
Ag. Economists
USDA/ESCS
Washington, D.C.

Edward Weiler
Ag. Economist
EPA/OPP/EAB
Washington, D.C.

March 31, 1980

Arsenic Trioxide

Arsenic Trioxide—Rodent Control

Arsenic trioxide is probably one of the oldest poisons still in use today and has been used since the 13th century as an instrument to combat vermin (Crabtree, 1961).

It is reported to have an acute oral LD_{50} between 8 and 500 mg/kg (Packman, *et al.*, 1961) depending on the species of test animal, particle size, solubility, and impurities. Merck Index (1968) reports an acute oral LD_{50} of 138 mg/kg, and Packman, *et al.* (1961) reports a dietary LD_{50} of chemically pure arsenic trioxide to rats at 133 to 225 mg/kg depending on the bait material. Arsenic trioxide solution is expected to be more toxic than the dry bait (Redeleff, 1964). Harrison, *et al.* (1958) reported a 96-hour LD_{50} for gastric intubation in rats of 15.1 to 39.4 mg/kg.

Methods of Application

Arsenic trioxide may be mixed with water or in various materials, such as bread crumbs, cookie meal (or crumbs), animal feed, dog food, etc. This "bait" may be placed in the rat's runways, watering, or feeding locations. The mixed bait usually contains from 1.5 to 3% (by weight) arsenic trioxide, depending on the bait material.

Use Patterns and Efficacy

Manufacturer, registration number, and other pertinent information are presented in Table 28.

Table 28.--Companies with labels registered for arsenic trioxide for use in rodent control^a

EPA Registration Number	Company	Active Ingredient
		Percent
422-5379	Blueball Chemical Co.	1.5
505-1	S. L. Cowley & Sons Mfg. Co, Inc.	1.5

^a Source: Survey of Manufacturers, 1979.

Arsenic trioxide has been repeatedly tested as an aqueous rat bait by the EPA. It is used by trained personnel in special cases, because its effectiveness is somewhat questionable unless extreme care is used in application. When test rats are exposed to water containing As (1.5% As_2O_3), the resulting mortality has not met EPA efficacy requirements of 90% mortality within 3 days of exposure (FIFRA Docket 341, 1976).

Exposure Analysis

The use of arsenic trioxide in the home, without benefit of protective bait stations, may create an unnecessary exposure risk to children. When properly placed outdoors or in commercial warehouses or similar areas, however, arsenic trioxide should present a very low exposure risk to humans and non-target animals.

Fate in the Environment

Arsenic trioxide is slowly oxidized to the pentavalent state. Reactions in the environment have been discussed in Volume I, Chapter 4.

Alternatives

Numerous alternatives to arsenic trioxide are registered and available. Other alternatives, if they continue to be available, may provide better control than arsenic trioxide. These alternatives are:

- Zinc phosphide
- 1080, 1081 (1080 and 1081 are under RPAR)
- Antu (Alphanaphthylthiourea)
- Anticoagulant compounds
 - Chlorophacinone
 - Diphacinone
 - Fumarin
 - Pival
 - PMP
 - Warfarin
- Red squill (where safety is a factor)
- Phosphorus paste (under RPAR)
- Strychnine (mice only, under RPAR)

Summary of Biological Analysis--Arsenic Trioxide

The use of arsenic trioxide as a rodenticide is apparently very limited based upon available registration labels. Aqueous baits, as evidenced by EPA test data, may not be readily accepted by rodents and therefore may not be considered efficacious. There are several alternatives which provide good control.

Economic Impact Analysis of Canceling Arsenic Trioxide

Arsenic Trioxide--Rodent Control

Introduction

The following report is an analysis of the potential economic impact of canceling arsenic trioxide usage as a rodenticide. This analysis is qualitative in nature due to the lack of data or experimental findings needed to support precise quantitative estimates. Although the impacts are in some cases reported as point estimates, they represent general approximations of arsenic trioxide use and economic impacts rather than precise statistical estimates.

Current Use Analysis

EPA Registrations of Arsenic Trioxide and Alternatives.--Arsenic trioxide is registered in liquid formulations for control of commensal rodents (house mice and rats) and in pelletized or dry bait formulations for control of moles and pocket gophers. All forms contain 1.5% active ingredient arsenic trioxide (EPA, 1979).

For house mice and rats, several alternatives are available including: Antu (adult rats only); chlorophacinone; diphacinone; fumarin; red squill (rats only); sodium fluoroacetate (RPAR); warfarin; strychnine (mice only); zinc phosphide; pival; and PMP. For moles and pocket gophers, strychnine⁸ is the only registered chemical alternative (Tracor Jitco Inc., 1979). Various non-chemical alternatives are also available for control of both commensal and burrowing rodents (e.g., sanitation, mechanical devices, and modification of structures to limit rodent access).

⁸ Strychnine RPAR does not include below ground uses.

Arsenic Trioxide Use Patterns.--The usage of arsenic trioxide as a rodenticide is estimated to be less than 1,000 pounds active ingredient annually (EPA estimate). Precise data are not available, but approximately 85% of all arsenic trioxide is used for control of commensal rodents with the remainder used for below ground control of moles and pocket gophers. Geographically, most usage is in the southeastern United States (EPA estimate).

For commensal rodent control, liquid arsenic trioxide is placed in jar tops or similar sources of drinking water at locations frequented by mice and rats. For moles and pocket gophers, roughly two teaspoons of arsenic trioxide pellets are inserted in mole tunnels or burrows. After baits are placed, the tunnels or burrows are closed by plugging the openings or pulling together or rolling back the turf.

Impact Analysis

Commensal Rodents.--Resistance to anticoagulant rodenticides (e.g., warfarin, fumarin, diphacinone, chlorophacinone) by rats has been documented in several U.S. cities, but a biological evaluation of the long-term viability of these chemicals as alternatives to arsenic trioxide is not available for inclusion in this analysis.

Several alternatives are registered and currently in use for control of house mice and rats (Tracor Jitco Inc., 1979). Costs of alternatives vary according to concentrations of active ingredient, formulations (liquids, grain baits, tracking powders, and pellets), application rates and package sizes. Some alternatives are acute toxins (e.g., zinc phosphide and strychnine), whereas others may take several feedings over several days to be effective (e.g. anticoagulants).

Alternatives are readily available, in common use, and are generally similarly priced (Table 29). This does not mean that specific alternatives are equally cost effective. Many factors ultimately determine the cost effectiveness of rodenticides. In specific cases, alternatives may be more cost effective than arsenic trioxide, and in other cases less cost effective. An accounting of these factors is not possible with data available at this time. Consequently, a quantitative comparative cost analysis of arsenic trioxide and alternatives has not been included; however, given that alternatives are more or less similarly priced, it is reasonable to conclude that significant economic consequences are unlikely if arsenic trioxide usage is canceled. A more detailed biological evaluation of arsenic trioxide and alternatives is needed before more definitive economic effects can be estimated. In general, a more detailed biological analysis would not alter substantively the conclusions of this analysis, but would enable more precise estimation of the nature and extent of economic effects.

Moles and Pocket Gophers.--Strychnine is the only registered chemical alternative for use on moles and pocket gophers. Based on available prices for similar container sizes, strychnine is slightly more expensive than arsenic trioxide (on the average about \$0.11 per container⁹). If one assumes that the efficacy of arsenic

⁹ Strychnine costs about \$2.19 per 4 oz. container, whereas the weighted average price of arsenic trioxide is \$2.08 per 4 oz. container (range of 1.25 to \$2.50).

Table 29.--Prices of arsenic trioxide and selected alternatives for control of commensal rodents, 1979^a

Rodenticide	Bait Form	Active Ingredient	Package Size	Price
		Percent		Dollars
Arsenic trioxide	Liquid	1.5	6 oz. container	1.19 per container
Diphacinone	Grain	0.1	5 lb. drum	1.70-1.97 per pound
Diphacinone	Pellets	0.005	4 oz. package	0.54 per package
Diphacinone	Pellets	0.005	1 lb. package	1.59 per package
Warfarin	Grain	0.5	5 lb. drum	1.74 per pound
Pival	Grain	0.5	5 lb. drum	1.78 per pound
Fumarin	Liquid	0.025	6 oz. bottle	3.25 per bottle
Chlorophacinone	Mineral oil	0.28	Quart	15.00 per bottle
Chlorophacinone	Dry concentrate	0.1	5 lb. canister	2.75 per pound
Chlorophacinone	Paraffinized pellets	0.005	25 lb. drum	1.20 per pound
Chlorophacinone	Tracking powder	0.2	1 lb. canister	2.50 per pound
Chlorophacinone	Paraffin blocks	0.005	2 oz block	0.14 per block
Chlorophacinone	Canary seed	0.005	1 lb. canister	1.75 per pound
Chlorophacinone	Ready-to-use bait	0.005	40 lb. carton	0.53 per pound

^a Sources: EPA, 1979a.

trioxide and strychnine is roughly equivalent, the impacts of using strychnine could increase user costs in the aggregate by less than \$5,000 annually.¹⁰ These cost increases would have negligible impacts on individual users in southeastern States and would not be of national economic consequence.

Summary of Economic Impact Analysis of Cancelling Arsenic Trioxide

Arsenic Trioxide—Rodent Control

- A. USE: Rodents.
- B. MAJOR PESTS CONTROLLED: House mice, rats, moles, pocket gophers.

¹⁰ The precise value of the economic impact cannot be publicly released or discussed because the estimate is based on proprietary business data. These data are entitled to treatment as trade secret or proprietary data under Section 7(D) and Section 10 of FIFRA as amended. Disclosure of the methodology for calculating this estimate would enable precise calculation of proprietary production data.

C. ALTERNATIVES:

Major Chemical Alternatives:

House mice and rats:	chlorophacinone	zinc phosphide
	diphacinone	pival
	fumarin	PMP
	sodium fluoroacetate (RPAR)	warfarin

House mice only: strychnine

Adult rats only: Antu
red squill

Moles and pocket gophers: strychnine

Non-Chemical Controls:

Trapping, sanitation, and modification of structures to limit rodent access.

Comparative Efficacy:

House mice and rats: Alternatives are available and generally effective; some anticoagulant resistance is developing in rats.

Moles and pocket gophers: Strychnine is available and effective.

Comparative Costs:

House mice and rats: Alternatives are similarly priced.

Moles and pocket gophers: Strychnine is slightly more costly.

D. EXTENT OF USE: Less than 1,000 pounds a.i. annually.

E. ECONOMIC IMPACTS: House mice and rats: No economic impacts of national significance are expected.

Moles and pocket gophers: Some user control cost increases totaling less than \$5,000 annually.

F. SOCIAL/COMMUNITY IMPACTS: Not investigated due to lack of comparative efficacy and comparative performance data.

G. LIMITATION OF THE ANALYSIS: Lack of comparative efficacy and comparative performance data on arsenic trioxide and alternatives.

H. PRINCIPAL ANALYSTS AND DATE: Roger C. Holtorf
Agricultural Economist,
EAB/BFSD/OPP/EPA
Washington, D.C.

John R. Parks
Agricultural Economists,
NRED/USDA
Washington, D.C.
Jan. 1980

Calcium Arsenate

Calcium Arsenate—Turf

Calcium arsenate is used to control Poa annua on recreational turf areas by creating a soluble As pool in the soil which kills germinating-sensitive weed species. Calcium arsenate is applied only by professional turf managers and current use and production is very limited owing to companies' hesitation to upgrade manufacturing plants to meet OSHA regulations and while uncertainties attendant to EPA's RPAR decision exist.

Lead arsenate has been used as an insecticide on golf greens since 1890, and owing to As accumulation, many greens were completely free of Poa annua. Calcium arsenate was used on turfgrasses (as a herbicide) based on experimental work first done at Purdue University in 1954. Between 1954-1960, numerous companies provided the following granular formulations (the preferred form for turf application).

<u>Product</u>	<u>Source</u>
Pre-Kill	Vaughn Seed Co.
Crabgrass Seed Killer	Sears, Roebuck & Co.
PAX	PAX Co.
Chip-Cal	Chipman Chemical Co.
STOPPS	Indiana Farm Bureau
Di-Met P.C.C.	O. E. Linck Co.
granular	General Chemical Co.
calcium arsenate powder	several companies

Table 30 lists manufacturers, registration numbers, and other pertinent data for calcium arsenate for those with turf application labels. Lead arsenate insecticide created toxic concentrations on putting greens and other types of professional turf, which resulted in simultaneous control of undesirable weed species. Calcium arsenate was a more economical source of arsenate, and in granular form was more easily calibrated and applied. In England, tests with calcium arsenate gave good insect (worm) control, and weeds were also reduced (Escritt, 1958).

Poa is an undesirable grass where hot-weather use puts a strain on it. For this reason, Poa is not suitable for golf courses or parks where heavy use occurs during the hot summer months. As non-arsenate crabgrass preventors became available (DCPA, benefin, Betasan, and siduron) during the 1960's, the non-professional market turned to these safer products for crabgrass control. Professional turf managers, however, continued to use calcium arsenate because its performance was more reliable than the alternatives.

Table 30.--Companies with labels registered for calcium arsenate use on turf areas^a

EPA Registration Number	Company	Active Ingredient
		Percent
359-360	Rhone-Poulenc	48.0
769-466	Woolfolk Chemical Co.	48.0
769-467	Woolfolk Chemical Co.	70.0
962-93	Los Angeles Chemical Co.	70.0
5535-35	J & L Adikes Inc.	48.0

^a Source: Survey of Manufacturers, 1979.

By 1972, the Chip-Cal granular was the only form of calcium arsenate available. It was successfully promoted, and over 3 million pounds were being used annually. It is estimated that it was used on more than 1,000 golf courses, many athletic fields, and other professional turf areas (Kerr and Daniel, 1969). Rhodia, Inc., of France bought Chipman Chemical Co., a family-owned business and soon closed all plants that were not capable of meeting OSHA air standards, which stopped production of Chip-Cal. By 1976, no calcium arsenate was being manufactured in the United States because of OSHA and pending EPA-RPAR decisions. The bartering of available granular Chip-Cal reserves was brisk. By 1977, only a few turf installations had small reserves of granular Chip-Cal (48% tri-calcium arsenate). The supply of calcium arsenate was soon exhausted, inasmuch as no company was manufacturing because of OSHA regulations, even though the product had been well researched, well labeled, and had been sold nationally for approximately 20 years. Meanwhile Poa annua continues to be the most serious weed problem in the United States, Canada, and Europe (Kerr and Daniel, 1969a).

Methods of Application

The first formulation available was powdery calcium arsenate, either 72% or 85% tri-calcium arsenate. For application by sprayer, a rate not to exceed 1 pound of product per gallon of liquid was recommended. This was kept in suspension by agitation and dispersed through large flood jet or T-jet nozzles, which minimized particle bridging and nozzle blockage. Applications of the powdery material were sometimes made early in the day while the turf was wet, followed by watering to remove the powder from the foliage. Later, granular particles (about like fertilizer) were spread by either drop-type hopper or broadcast sling-type applicators. Arsenic is effective against susceptible plants and insects only when present in toxic concentrations in the soil. Programs of application that have been used are listed in Table 31.

Use Patterns and Efficacy

The target species, Poa annua, annual bluegrass, persists until weather or other adversity kills it. Poa annua produces seed profusely, primarily in the early spring and summer. The seed will germinate in most months of the year, except in the hottest months in the South. When Poa annua persists as a partial stand within bluegrass or bentgrass, it can be selectively removed or eliminated by the use of arsenicals. Under such professional management, turf areas were cleared of Poa

Table 31.--Suggested rates for Chip-Cal granular per 1,000 square feet

Phos- phorus Test	Appli- cation Season	Percent <u>Poa annua</u>					Total To Reach <u>Poa</u> , Crabgrass, Goosegrass, and Soil Insect Toxicity	Soil Type ^a
		70-90	50-70	30-50	15-30	Under 15		
----- <u>Pounds</u> ^b -----								
Low	Fall	4	6	8	10	12	16 - 20	Light sandy loams
	Spring	4	6	8	8	6		
	Fall	4	4	4	2	2		
	Spring	4	4	--	--	--		
	Fall	2-4	--	--	--	--		
Medium	Fall	6	8	8	10	12	20 - 24	Loams
	Spring	6	8	8	8	8		
	Fall	6	4 + 4	4 + 4	4-6	2-4		
	Spring	4-6	2-4	--	--	--		
High	Fall	6	8	8	10	12	24 - 30	Buffered clay and silt loams
	Spring	6	8	8	8	8		
	Fall	6	4 + 4	4 + 4	6	6		
	Spring	6	2-4	4-6	4-6	2-4		
	Fall	4-6	--	--	--	--		
		Reseed often	Reseed often	Reseed as needed	Reseed if needed	Reseed if needed		

^a Soils with low buffer capacity, low organic matter, less phosphorus, and poor drainage require less arsenical to reach toxicity levels. After restriction (Poa annua is yellow, thin, weak), then use annually 2 to 3 pounds per 1,000 square feet to maintain toxicity. Reseed to improved varieties with vertical grooving as often as conditions permit.

^b Pounds per 1,000 square feet are expressed as 48% Chip-Cal granular or 48% Tri-Calcium Arsenate.

annua, and many times achieved stands of perfect bluegrass, bentgrass, or Bermuda-grass, depending on the area of adaptation. In addition to Poa annua, other As-susceptible plants include: the crabgrasses, Digitaria sanguinalis and D. ischaemum; the foxtails; barnyardgrass; sandbur; common and mouse-ear chickweed; plus a limited number of other weedy annuals and viney perennials. In contrast, the perennial turf-type grasses including bluegrass, Poa pratensis; ryegrasses, Lolium perenne; red fescue, Festuca rubra; Bermudagrass, Cynodon dactylon; zoysia, Zoysia japonica are more tolerant, and whereas the susceptible species are completely obliterated from the turf stand, the tolerant species fill in by rhizome, stolon growth, or seed placement. Because of this selectivity, it was possible to prescribe arsenical treatments for individual areas to achieve and maintain toxicity. It was estimated that at least 2,000 golf courses, as well as hundreds of other turfs managed by professionals, had at least one area on which Poa annua and other weedy grasses were under control at the time calcium arsenate became unavailable.

The efficacy of arsenicals is increased when no soluble phosphorus fertilizer is applied (Kerr and Daniel, 1969a). Therefore, special formulations without phosphorus became available for the turf trade. Products such as 20-0-16 were offered for putting green and professional turfgrass use so that As toxicity could be maintained. Arsenic was used throughout the northern two-thirds of the United States on athletic fields, golf greens, fairways, tees, parks, and playgrounds. The predominant use, however, was on golf course turf, particularly greens and fairways where *Poa annua* is the greatest problem in cool season turf. A golf course may have 30 acres of fairways, 3 acres of greens, and 2 acres of tees. Approximately 3 million pounds of calcium arsenate were sold and distributed annually before Chipman Chemical Co. stopped their production (Kerr and Daniel, 1969a).

Exposure Analysis

Although turf managers used varying types of equipment for the application of calcium arsenate, the time of exposure was usually limited to an application period covering not more than 2 weeks a year. With the use of granular formulations and broadcast-type application, applicator contamination was reduced. The larger particles did not blow, but tended to fall off the turf onto the ground surface. The product was colored pink for identification purposes, and as a warning the bags carried the picture of a skull and crossbones. Most golf courses used the same employees to make the applications each year. There is one case of extreme exposure worth noting: In 1958, a golf course superintendent hand-mixed Milorganite and powdered calcium arsenate but did not use enough Milorganite to separate the powder, to allow the material to flow properly during application. He applied the mixture to nine fairways over a 2-week period, doing all handling of the material and insuring proper flow by stirring with his bare hands. During this period, he was exposed to calcium arsenate because of his faulty techniques. As a result, he lost his sense of taste, had a skin rash around his genitals, and felt ill for 3 to 5 days. Within 1 month all symptoms ceased. He continued to use arsenicals until his retirement in 1976 and is in good health at this time (Daniel, 1980).

Fate in the Environment

Many of the uses of arsenicals as presented by this Assessment Team are those employed to achieve a toxicity that persists in wood or in soil (Daniel and Freeborg, 1970). In turf applications, a suitable concentration of the available soil As is desired, which causes seedling failure to susceptible species (Freeborg, 1971). As a result, when heavy rains occurred on golf courses where calcium arsenate was applied and watered in, little evidence of movement or accumulation of As was observed in drainage areas. (In contrast, Kerb[®] is moved by rain and will streak across roughs or along drainways.) Small amounts of calcium arsenate may accumulate in drainage areas because of extensive surface treatment and erosion.

Arsenic, like phosphorus, is attracted to soils and sorbed to the soil complex primarily at the soil clay surface where it first comes in contact. Extensive work by Freeborg (1971) and others showed that a downward movement through the profile occurs only very gradually, and over long periods this downward movement is limited to the upper 2 to 4 inches. One application of calcium arsenate made on an unfertilized lawn for crabgrass prevention was effective for 18 years. On an adjacent lawn where other nutrients, nitrogen, potassium, etc., were applied, toxicity lasted for 13 years. In general, the larger the exchange capacity of the soil and the higher the organic matter, the larger the application of As required. There is evidence that two or three applications of calcium arsenate suddenly achieve toxicity when combined with specific weather conditions.

The seed of most plants accumulates enough phosphorus to carry the germinating seedling to about a three-leaf stage for grass or approximately 1 month of seedling growth. At this point, the root system of the seedling must obtain its phosphorus from the root zone. Where As is present in sufficient quantity to cause toxicity to susceptible plants, both mature plants and seedlings are restricted, and under adversity will die. (In greenhouse studies, plants, where growth is restricted by As, have stayed alive for several months, but when phosphorus is applied, these plants resume normal growth within 7 to 14 days.) For a general discussion of As in the environment, see Volume I, Chapter 4.

Alternatives

Chlordane became widely available and replaced lead arsenate as the standard insecticide, but is no longer available for this use. Meanwhile, calcium arsenate was not favored for homeowner use because of a potential hazard. During the period 1959-1964, several pre-emergent materials became available, the first of which was DCPA (Dacthal[®]), sold as Rid by Swift & Co. The DCPA is merchandised by more than 50 formulators, and is used extensively for the prevention of annual summer-type grasses, primarily crabgrass. Benefin is also widely distributed as the product Balan[®]. Two pounds per acre of active ingredient prevents a crabgrass and weedy summertime grass infestation. The products Betasan[®] (Stauffer) and Siduron (Tupersan[®], Du Pont) have proven effective in preventing crabgrass germination for 60 to 90 days. In humid areas, these products have proven adequate for annual homeowner and lawn care use. The standard recommended rate for crabgrass plus a supplemental rate at one-half that level in early summer is recommended for tees, fairways, and athletic fields where goosegrass, Elusine indica, is a problem. In the South, pronamide, (Kerb[®], Rohm & Haas), gives both Poa annua and cool-season grass control. It is used on Bermudagrasses in mid-spring to kill the cool-season grasses and release the entire area for Bermudagrass growth during the summer. This provides an annual control from existing Poa annua plus some inhibition against weedy grass infestations.

The alternatives listed above have not eliminated Poa annua in professional turf areas of golf greens, fairways, football fields, and parks because of persistent seedling germination.

Calcium Arsenate—Slug and Snail Bait

Calcium arsenate is used in bait form for the control of slugs and snails in a wide variety of plant crops. The bait is formulated with 5% calcium arsenate and 2% metaldehyde in pellets or flake-like materials. Application rates vary from 22.4 to 56.0 kg of bait per hectare with one or two treatments per season. Human exposure is very minimal because there is little contact with the bait. Some alternatives are nearly as effective, but cost significantly more to use.

Calcium arsenate was used as an insecticide prior to 1907 (Pickering, 1907), but Smith (1908) noted that it was not being marketed in New Jersey in 1908. The first extensive use of calcium arsenate was on cotton in 1919 (Coad and Cassidy, 1920) for boll weevil control. Its first use in baits for slug and snail control is not known, but may have resulted from studies reported by Lovett and Black (1920). They found a bait mixture of calcium arsenate and chopped lettuce to be suitably effective for control of the garden slug in Oregon. In a subsequent eradication program against the white snail, Helix pisana, Basinger (1927) successfully substituted bran for the

lettuce by mixing one part of calcium arsenate by weight with 16 parts of bran and adding water to make a friable mash. The same bait mixture was later recommended by Basinger (1931) for use against Helix aspersa Müller, then known as the European brown snail.

In 1934, metaldehyde was reported to be an effective molluscicide, and confirmatory studies were undertaken and marketing of commercial baits started in 1938. Metaldehyde baits appeared to attract slugs and snails more effectively than calcium arsenate baits, but provided lower kills. Combining the two materials with an appropriate bait substrate provided Lange and MacLeod (1941) with the most effective baits in tests on artichokes and in garden areas. Most subsequent uses of calcium arsenate for slug and snail control have been in combination with metaldehyde and commercial baits marketed in recent years have been predominately of this type. No calcium arsenate baits are currently being used for reasons discussed in the turf portion of this chapter. Table 32 lists those companies who have registrations for bait applications.

Table 32.--Companies with labels registered for calcium arsenate use as a slug and snail bait^a

EPA Registration Number	Company	Active Ingredient
		Percent
239-23	Chevron Chemical Co.	5.0
239-74	Chevron Chemical Co.	5.16
239-111	Chevron Chemical Co.	5.16
239-561	Chevron Chemical Co.	5.16
359-536	Rhone-Poulenc	5.16
476-1092	Stauffer Chemical Co.	6.75
476-1551	Stauffer Chemical Co.	5.16
728-23	Southland Pearson	5.0
912-91	Farmer's Union Central	5.16
1386-447	Universal Cooperative	5.0
6720-70	Southern Millcreek Products	5.0
7001-141	Occidental Chemical Co.	5.0
11656-22	Western Farm Services	5.0

^a Source: Survey of manufacturers, 1979.

Methods of Application

Practically all uses of calcium arsenate for slug and snail control involve bait preparations in flake or pellet form. Low-cost edible materials are normally used as the substrate material. Distribution is frequently accomplished with mechanical equipment in order to provide a broadcast pattern onto ground surfaces, but much is manually applied. In many cases, it is desirable to place the bait around the base of plants for full effectiveness or to apply the bait in a manner to avoid the contamination of the edible plant part (e.g., strawberries). In such cases, manual applications may be preferred or necessary.

Use Patterns and Efficacy

Label specifications indicate a potentially extensive use of calcium arsenate baits for slug and snail control, but it is recognized that, in actual practice, applications on many of the crops and sites included on such labels are restricted to localized and/or temporal needs brought about by unusual weather conditions, predisposing cultural practices or other transitory influences. Table 33 summarizes the crops and non-crop sites listed on labels where calcium arsenate may be used for slug and snail control.

It was not possible to specify which of these labeled uses are individually recommended by State agricultural experiment stations or, even more explicitly, the actual regional uses by acreage or poundage on individual crops and other sites. Actual usage will vary greatly depending on weather (rainfall) conditions. In California, control recommendations are made for slug and/or snail control on such crops as artichokes, broccoli, brussels sprouts, cabbage, cauliflower, citrus, strawberries, and tomatoes. Somewhat different listings would be expected from other States, but in the aggregate the number of crops and acreages potentially requiring treatment could be significantly high. Added to these uses are the needs for control in nurseries, greenhouses, lawns, home garden, and ornamental plantings.

The efficacy of calcium arsenate bait treatments is almost universally enhanced by the inclusion of metaldehyde in the formulation. Such baits, commonly constituted with 2% metaldehyde and 5% calcium arsenate on a bran or other suitable substrate, will frequently provide pest mortalities in the range of 90%. This upper level of efficacy reflects, in great part, the fact that at the time of any treatment, a part of the pest population may be secreted in non-exposed areas or may not be actively feeding during the baiting period. This, coupled with the high reproductive potential of some species, results in the need for a schedule or sequence of treatments throughout the season, particularly on permanent or semi-permanent croppings. Application rates are usually in the range of 20 to 50 pounds of bait per acre (22.4 to 56.0 kg/ha) with one or two treatments per season.

Exposure Analysis

Once the bait has been formulated and packaged, exposures are limited to accidental or purposeful openings of the bag or other container. Accidental openings and spillages would primarily involve ground surface contaminations because of the aggregate and relatively heavy nature of the bait formulation particles. The possibilities for exposure of humans, livestock, pets, or other animal forms to such ground contaminations could be almost entirely eliminated by the immediate and proper implementation of retrieval, dissemination, or burial procedures. Such accidental spillages could also predispose to limited, but removable, dermal contaminations or to limited respiratory intake if fines or dust were present in the formulation.

In the purposeful use of calcium arsenate bait formulations, only very limited exposures would result from the opening of the shipping container and the transfer of the material to a hopper on a mechanical dispensing unit or into a hand-carried container. Most pelletized bait preparations are essentially dustless, but along with flake-like baits, would pose the possibility of limited air dispersions which could be a source of respiratory intake. Such air-dispersed particles would tend to be trapped in the nasal passages and, after migration into the throat, would be expectorated or swallowed.

With either pelletized or flake-like baits, spillages would not generally result in the extensive retention of bait particles on skin or clothing surfaces. With

Table 33.--Sites where calcium arsenate slug bait is registered for use

Tree Crops

Apples	Grapefruit	Peaches
Apricots	Lemons	Pears
Avocados	Nectarines	Plums
Cherries	Oranges	

Small Fruit Crops

Blackberries	Loganberries	Strawberries
Boysenberries	Raspberries	

Vegetable and Field Crops

Asparagus	Celery	Mustard greens
Beans	Collards	Onions
Blackeyed peas	Corn	Peppers
Broccoli	Cowpeas	Pumpkins
Brussels sprouts	Cucumbers	Rutabagas
Cabbage	Eggplant	Spinach
Cantaloupes	Kale	Squash
Carrots	Kohlrabi	Tomatoes
Cauliflower	Melons	Turnips
		Watermelons

Non-crop Sites

Commercial-inedible-outdoor	Lawns
Domestic dwellings--outdoor	Non-crop areas
Flowering plants	Nurseries
Greenhouses	Ornamental plants
Lathhouses	Terrestrial structures

dermal and respiratory intakes largely restricted, exposures from handling bait preparations would be primarily limited to the accidental conveyance of pellets or flakes into the mouth by the worker. The precautionary and personal work habits of the individual would determine the likelihood of such exposures.

Calcium arsenate baits, stored where children have had access to them, have been a source of poisoning episodes. It should also be noted that dogs have been killed by ingesting calcium arsenate-metaldehyde bait pellets. The palatability of the pellet substrate and possibly the resemblance in appearance to prepared dog foods appear to account in part for the attractiveness of applied baits to the animals. The problem also appears to be greatest when metaldehyde is one of the bait inclusions. In some cases, repellents such as capsicum have been incorporated to make the baits unattractive to dogs. The incidence of poisonings has also been sharply reduced by substituting ground paper, sawdust, and other less palatable materials in the bait substrate.

Alternatives

Metaldehyde has long been recognized as an effective treatment for slug control (Mead, 1961), and is independently effective in baits or granular formulations for snail control providing the compound inclusion in the preparations is approximately 7 to 10%. Low percentage metaldehyde baits, such as those supplied for home garden use, provide inadequate control in agricultural uses for snail control, resulting in the need for more frequent treatments.

The more recent studies of Getzin and Cole (1964), Crowell (1967), Judge (1969), Judge and Kuhr (1972), and others have demonstrated the molluscicidal properties of materials such as aldicarb (Temik®), methiocarb (Mesuro®), methomyl, phorate (Thimet®), and thionazin (Zinophos®). The latter compound is no longer produced by the American Cyanamid Co. and aldicarb, methomyl, and phorate labels do not specify uses for the control of slugs or snails.

Methiocarb is clearly a potential alternative treatment, but is not registered by EPA for use in slug and snail control for reasons that have not been clarified. It is registered for use in spray applications on certain deciduous fruit trees, and this coupled with the issuance of special local need registrations for slug and/or snail control on such crops as artichokes and citrus suggests that broader registration coverages may be provided at some future time. Baits of methiocarb, or especially of methiocarb in combination with metaldehyde, have been found to be very effective against the brown garden snail, and in favorable formulations have the prospect of providing more effective treatments than those obtainable with calcium arsenate-metaldehyde baits (Carman and Passas, 1979), although at a higher cost per acre.

Calcium Arsenate—Fly Control

House fly larvae are found in untreated animal manures. Subsequent development and emergence of house fly adults is a serious public health problem. In the southeastern U. S., lack of control of the house fly associated with poultry operations has reached epidemic proportions. Therefore, treatment procedures for the larvae in animal manures are urgently needed.

Mechanical and chemical procedures for treating animal manures are available that act to control house fly larvae. Calcium arsenate is one chemical treatment that is effective and economical to use as a house fly larvicide. Resistance to this compound has not developed. In contrast, resistance to synthetic organic compounds develops quickly. When calcium arsenate is used as recommended, few environmental problems are encountered.

Calcium arsenate is used as a spray application to control house fly larvae in poultry manure. It is applied at 2.5 pounds of a 70% formulation in 4 gallons of water. This amount covers 1,000 sq. ft. of droppings beneath caged poultry.

Companies with registered labels and their products are presented in Table 34. No calcium arsenate is currently being used or manufactured because companies are unwilling to invest capital to meet OSHA Air and Exposure Standards until a decision is made by EPA under the RPAR process. Two companies, however, have expressed

Table 34.--Companies with labels registered for calcium arsenate use for fly control^a

EPA Registration Number	Company	Active Ingredient
		<u>Percent</u>
769-374	Woolfolk Chemical Co.	70.0
769-443	Woolfolk Chemical Co.	70.0
962-93	Los Angeles Chemical	70.0

^a Source: Survey of Manufacturers, 1979.

interest in reestablishing markets for calcium arsenate (Alden, 1980; and Mitchell, 1980).

Methods of Application

Calcium arsenate is applied at 1.6 pounds of active ingredient per 1,000 sq. ft. as a low-pressure (30 to 60 psi) spray. The droplets are large, with little drift, and are applied by conventional power sprayers equipped with flat fan or cone-type nozzles. Sprays are directed, not broadcast, as banded treatments under cages of layers and as spot treatments to manure piles. This application technique is used to prevent contaminating poultry and livestock, or their feed.

Use Patterns and Efficacy

Coarse sprays are applied under caged poultry on a preventive schedule at 5- to 7-day intervals when needed. If house fly maggot populations begin to increase, coarse sprays are applied at a 3- to 4-day intervals until control is achieved. Treated manure cannot be used for fertilizing pastures, food, or feed crops.

Calcium arsenate is an effective house fly larvicide. Although no calcium arsenate is currently used, it would be the most widely used compound for this use if it were available. No buildup of resistance to calcium arsenate is known.

Exposure Analysis

Directed large droplet (coarse) sprays are applied with low-pressure (30 to 60 psi) power equipment or hand-operated compressed air sprayers. Protective clothing, (i.e., rubber boots, coveralls, gloves, goggles, and a protective mask) are used by applicators. This greatly reduces the possibility of operator exposure to calcium arsenate during mixing and spraying.

Treated litter is handled by hand-operated mechanical devices or power equipment which precludes the occurrence of significant contact between the treated material and the operator. Specific exposure analysis data, with the use of this application technique, are not available.

Fate in the Environment

To a great extent, the application techniques used prevent drift of spray particles. It is felt that little of the calcium arsenate used for fly control ends up in the air because it is applied in large droplets. The use of calcium arsenate as a fly larvicide will not contaminate water because no direct application is likely. Calcium arsenate-treated manure is only applied to fallow land and, therefore, would end up in contact with the soil. It is applied so that contact with plants and animals is largely prevented. The As content in manure varies from 1 to 10 ppm As. At application rates of 4 tons manure per acre, manure would add 0.008 to 0.08 pound As to each acre. This is insignificant when compared to background levels of 10 to 20 pounds As in each acre to a depth of 6 inches. For a further discussion on the fate of As in the environment, see Volume I, Chapter 4.

Alternatives

Manure must be made unsuitable for house fly development by using mechanical or chemical measures. Mechanical measures include hauling manure to a suitable site for disposal on a 3- to 4-day schedule, or maintaining a moisture content F25% or J75%, conditions which prevent house fly larva development. Chemical measures would include larvicides such as naled, dichlorvos, dimethoate, fenthion, malathion, chlorfenvinphos, and ronnel. Calcium arsenate was 25% less expensive than the alternative chemicals when it was available. Resistance to all synthetic chemicals develops quickly, often in less than a year. Fly larvae, however, do not develop a resistance to calcium arsenate.

Summary of Biological Analysis—Calcium Arsenate

Calcium Arsenate—Turf

Calcium arsenate is approved (based on scientific research), and was sold throughout Canada and the United States over a period of approximately 20 years. It was the standard Poa annua control measure in professional turf areas because of its selective soil treatment behavior. It was used only by professional turf managers. Every program became an individual program based on the turf site, the history of the area, the turf manager's program, the climate, and subsequent management procedures.

A recent canvass of some courses where calcium arsenate was used previously indicated a continued interest in the chemical by the following courses if usage and availability could be assured (Kerr, 1980; Lucas, Jr., 1980; Fisher, 1980; and Paetz, 1980):

<u>Club</u>	<u>Contact</u>	<u>Location</u>
Woodway Club	Sherwood Moore	Connecticut
Cherry Valley Club	Hank Heddesheimer	Long Island
Deepdale	Charles Amorim	Long Island
Garden City Country Club	Stanley Bugaj	Long Island
Woodcrest Country Club	Lynn O'Neil	Long Island
Woodmere Club	Rick McGuinness	Long Island
Baltusrol Golf Club	Joe Flaherty	New Jersey
Bedens Brook Golf Club	Jim Gilligan	New Jersey
Montammy Golf Club	Mike Leary	New Jersey
Piping Rock Club	Mel Lucas, Jr.	New York
Edgewood Country Club	Lester Bishop	Ohio
Springfield Country Club	Kermit Delk	Ohio
Jack Nicklaus Golf Club	Richard Craig	Ohio
Mound Builders Country Club	Steve Eeve	Ohio
National Cash Register Golf Club	Jack Hart	Ohio
Camargo Club	Jack Johns	Ohio
The Country Club	Alfred Muhle	Ohio
Aurora Country Club	Carl Hoppfan	Illinois
Prestwick Country Club	Richard Trevarthan	Illinois
Short Hills Country Club	Thomas VandeWalle	Illinois
Meridian Hills Country Club	Steven Frazier	Indiana
Orchard Ridge Country Club	John Leeper	Indiana
Broadmoor Country Club	Oscar Miles	Indiana
Tippecanoe Lake Country Club	James Plumb	Indiana
Bidenmun Golf Club	Frank Staffieri	Delaware
Coatesville Country Club	John Nagy	Pennsylvania
Concord Golf & Country Club	Balbino Ramos	Pennsylvania
Green Hill Yacht & Country Club	Lou White	Maryland
Overbrook Country Club	Warren Savini	Pennsylvania
Talbot Country Club	Ralph McNeal	Maryland
White Manor Country Club	J. Wesley Pratt	Pennsylvania

It is estimated that up to 2,000 courses would use calcium arsenate "in approximately 3 years after the reintroduction of the product" (Kerr, 1980). Interest in resuming production has been indicated by two companies if sufficient labeling is left after the RPAR process is completed (Alden, 1980; and Mitchell, 1980). The labels of interest are for turf, fly larvicide in caged poultry, slug bait, and grapefruit (assuming EPA grants the request by Florida to switch from lead arsenate to calcium arsenate).

In a survey conducted by EPA (Plant Studies Branch, BFSB, OPP, OPTS), a random sample of potential users of calcium arsenate showed some support for the return of its use to control Poa annua in turf, some difficulties with its use when it was available and used, and some who were satisfied with the present turf management systems now available. These responses are summarized in Table 35. Included are results of a summary of testimonial letters received by the Assessment Team relative to the use of calcium arsenate on turf for Poa annua control. It was felt by most of the respondents that calcium arsenate was better than the alternatives available, had fewer problems, had little harmful effects when used properly, and has been used successfully at lower costs than the alternatives currently available.

Table 35.--Summary of letters for the use of calcium arsenate on turf for *Poa annua* control

Name ^a	Affiliation	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
J. A. Jagschitz	Univ. RI	X	X	X	X							X		X		Column Headings
Dr. Indyk	Rutgers Univ.			X	X										X	1. Calcium arsenate is selective.
D. Howell	Athens C.C.					X							X	X		2. Calcium arsenate has post-emergent activity which the alternatives do not.
C. R. Skogley	Univ. RI											X		X		3. All alternatives not as effective.
Dr. Kleeman	Univ of MD			X	X							X				4. No chemical alternatives available for post-emergence control.
J. Murray	Univ. of MD			X												5. Loss of calcium arsenate has resulted in greater usage of other chemicals.
M. Geesleman	Reston G.C.											X	X			6. No harm to personnel or environment.
P. Naples	G.C. Super. Assn.					X					X	X	X		X	7. Used with complete satisfaction.
P. Paetz	All Best Inc.						X	X								8. Lower cost per acre.
C. Hopphan	Aurora C.C.							X	X				X	X		9. Will return to using calcium arsenate.
M. Lucas, Jr.	Piping Rock C.C.							X		X						10. Wet seasons cause calcium arsenate to leach to low areas.
B. Orazi	Hunt Valley G.C.		X			X			X	X				X	X	11. Kerb effective in the S.E. United States in Bermudagrass turf.
J. R. Hall	VA Poly Inst.			X												12. Balan, Dacthal, Betasan or Azak can be used.
L. W. White	Green Hill Y & C.C.						X	X	X	X						13. Azak not available.
D. S. Alford	The Greens C.C.					X	X	X		X						14. Reseeding must be delayed with alternatives.
S. J. Zontek	U.S. GA Greens Section	X		X				X		X			X			
W. Davis	Golden Green						X	X		X						
R. Koppitz	Alva G. & C.C.						X	X		X						
R. W. Young	Meadow Lake G.C.						X	X		X						
Total Responses (19)	2	2	6	3	4	6	9	3	8	1	5	5	3	3		

^a For more information on the respondents, see references.

Calcium Arsenate—Slug and Snail Control

Calcium arsenate is effective for the control of slugs and snails in bait formulations that include metaldehyde. The bait is significantly cheaper than other materials on an annual per-acre basis. Exposure is minimal, because it is formulated in pellet or flake form with very little dust present. Application is normally done with hopper or broadcast equipment, but may be done manually. Slug control on a wide variety of crops may be necessary in unfavorable rainy years, such as California experienced in 1978.

A summary of testimonial letters received by the Assessment Team is presented in Table 36. The growers responding to an item in the Pest Control Circular (Feb. 1980) indicate a strong desire to continue the registration of calcium arsenate for the control of slugs and snails because it is more efficacious and costs less than the alternative materials while being used with good success.

Calcium Arsenate—Fly Control

Calcium arsenate is applied to house fly larva breeding areas under poultry cages and to manure piles by using application methods that prevent most contamination of animals, plants, soil, water, and air. When calcium arsenate-treated manure is removed from animal operations, it is normally applied to fallow land. This should not result in significant contamination of the environment by calcium arsenate. Little exposure to calcium arsenate is likely when applied in the recommended manner.

Economic Impact Analysis of Canceling Calcium Arsenate

Calcium Arsenate—Turf

Current Use Analysis

Arsenical pesticides were produced by more than 10 different chemical companies in the United States. Most of the various individual arsenicals, however, are produced by only one or two firms, and data on production are therefore difficult to obtain because such information is considered proprietary. The U.S. Tariff Commission reported some data on pesticide production (Table 37). Production of calcium arsenate has been falling steadily, as its use is replaced by organic phosphorus and carbamate compounds. Beyond these few published statistics, little data are available on the production of specific arsenicals.

There is very little published information on quantities used of the various arsenical pesticides, because in most cases they are not widely applied.

Calcium arsenate (or tri-calcium arsenate) is registered for use as a herbicide in lawns and ornamental turf. It was applied as a 48% granular at a rate of about 4 pounds actual per 1,000 sq. ft. (EPA label No. 962-93). It is a very efficacious compound (presented previously in this chapter).

The primary use of calcium arsenate was for the control of Poa annua (annual bluegrass) on the fairways, greens, and tees of golf courses. Poa annua is a weedy grass that is common on many golf courses and other managed turf areas around the country. In some places with mild climates, it is cultivated as the predominant variety of turfgrass because it does possess some desirable properties. Poa annua

Table 36.--Summary of letters for the use of calcium arsenate for the control of slugs and snails

Name ^a	Affiliation ^b	1	2	3	4	5	
N. D. Buehling	I	X	X	X	X		<u>Column Headings</u>
E. Pressey	I	X				X	1. Alternatives less effective.
A. M. Pomatto	I		X				2. Alternatives cost more.
H. C. McMillan	I	X	X		X		3. Used calcium arsenate with success.
D. A. Stevning	I				X		4. Continue the registration.
B. Hillebrecht	I	X	X	X			5. Alternatives must be applied more often.
G. W. Rahill	I	X	X	X	X		
G. B. McReynolds	I	X	X	X			
J. M. Daly	I	X	X	X	X	X	
J. E. Reimers	I	X	X		X		
C. R. Marshall	I	X	X	X	X		
E. Leibacher	I		X	X	X		
Total responses	12	9	10	7	8	2	

^a For more information on the respondent, see references.

^b I = Individual Growers.

Table 37.--Production of calcium arsenate^a

Year	Calcium Arsenate
	<u>1,000 Pounds</u>
1960	6,590
1961	7,944
1962	4,660
1963	3,310
1964	6,958
1965	4,192
1966	2,890
1967	2,040
1968	3,398
1969	1,158
1970	1,144
1971 ^b	940
1972 ^b	133
1973 ^b	357
1974 ^b	474

^a Source: (EPA, 1972a): Data since 1972 not available, but some produced through 1974. Purchased stocks still being used.

^b Source: Alden, 1980.

is generally healthy in the spring and fall, can be cut close, reseeds itself, and is tolerant of variations in soil nutrition. Poa annua is, however, susceptible to many climatic and use conditions easily tolerated by other species of turfgrass. It can be killed by continuous wear, it is easily smothered by ice and snow due to its high rate of respiration, and hot, dry winds will cause it to fail, as will hot, humid days and nights. Fairways of Poa annua have been known to wilt in an afternoon or be completely killed following a snowfall, leaving large areas that are difficult to play golf on and that must be reseeded (Keitt, 1979).

Because of the uncertainty associated with its ease of failure, many golf course superintendents decided to phase out Poa annua in favor of more desirable turfgrass species. The most common method of changing turf species involved the use of calcium arsenate to kill and maintain control over Poa annua. The initial phase of the changeover involved the application of large quantities of calcium arsenate to the turf for the first year or two to raise the level of residual arsenic (As) in the soil. Poa annua is considerably more susceptible to As than are the desirable species such as bentgrass, Kentucky bluegrass, and Bermudagrass. As the Poa annua was killed, the course was reseeded with the new species. The second phase of the program consisted of annual applications of small quantities of calcium arsenate to maintain the soil toxicity and prevent reinfestation by Poa annua (Keitt, 1979).

The amount of calcium arsenate applied during this type of program varied considerably due to climatic conditions, soil type, drainage, level of soil phosphorus, and many other factors. In the Midwest, golf courses typically applied about 15 pounds annually per 1,000 sq ft in the first 2 years and 2 to 3 pounds annually to maintain toxicity. In some East Coast areas, however, the quantities of calcium arsenate needed to control Poa annua were only one-third of those needed in the Midwest (EPA, 1972a).

Use of Calcium Arsenate and Alternatives

There are numerous registered alternatives to calcium arsenate (see Table 38). The best alternatives include bensulide (an amide compound), benefin (a toluidine), DCPA (a phthalic compound), terbutol, pronamide, siduron, and oxadiazon. These alternatives are more expensive and must be applied more than once a year. The substitutes are effective in controlling Poa annua but have some drawbacks. Some are phytotoxic to the seedlings of the new grass and do not have the residual effectiveness of calcium arsenate. Furthermore, the higher degree of phytotoxicity requires that a longer period of time be allowed between application of the herbicides and applying the new seed. Some of these alternatives present problems of leaching and lateral movement. This means that there may be die-off or a period of unsightly browning before the new grass matures (discussed previously in this chapter).

Economic Impact Analysis

The entire question of economic impacts of restrictive action by EPA against calcium arsenate turf herbicide is academic. According to Dr. Weinke, turf manager of the Chipman Division of Rhodia, Inc., the only manufacturer of granular calcium arsenate, they are currently not able to produce the calcium arsenate. Rhodia had been manufacturing the herbicide with their own equipment, but in another firm's plant. The other firm began receiving inquiries from the Occupational Safety and Health Administration (OSHA), presumably about the worker safety conditions of the calcium arsenate manufacturing process. Rather than risk restrictive action by OSHA, the firm refused to let Rhodia produce calcium arsenate in its plant. Rhodia has decided to drop regular calcium arsenate from its product line and not attempt to

Table 38.--Comparison of use patterns for calcium arsenate and other preemergent herbicides for weed control in turf (Information is derived from registered labels)

	Preemergent Herbicides							
	Calcium Arsenate ^a	DCPA ^a	Benefin ^a	Bensulide ^a	Siduron	Terbutol ^a	Pronamide ^a	Oxadiazon ^a
PESTS, TIME OF APPLICATION, ^b AND NUMBER OF APPLICATIONS								
<u>Crabgrass</u>	X	X	X	X	X	X	--	--
Early spring	X	X	X	X	X	X	--	--
Late summer	--	--	--	--	--	--	--	--
Early fall	--	--	--	X	--	--	--	--
Late fall	X	--	--	--	X	X	--	--
Late winter	--	--	X	--	--	--	--	--
<u>Number of treatments per year</u>								
Cool season	2	1	1	1	1	1	--	--
Warm season	2	1	1	2	1	1	--	--
<u>Annual bluegrass</u>	X	X	X	X	--	X	X	X
Early spring	X	X	X	X	--	X	--	X
Late summer	--	X	X	--	--	--	--	--
Early fall	--	--	X	X	--	--	--	--
Late fall	X	--	--	--	--	X	X	X
Late winter	--	--	--	--	--	--	X	--
<u>Number of Treatments Per Year</u>								
Cool season	2	2	1	1	--	1	0	1
Warm season	2	2	2	2	--	1	1	1
<u>Chickweed</u>	X	X	X	--	--	--	--	--
Early spring	X	X	--	--	--	--	--	--
Late summer	--	--	X	--	--	--	--	--
Early fall	--	--	--	--	--	--	--	--
Late fall	X	--	--	--	--	--	--	--
Late winter	--	--	--	--	--	--	--	--

Table 38.--Comparison of use patterns for calcium arsenate and other preemergent herbicides for weed control in turf (Information is derived from registered labels)--continued

	Preemergent Herbicides							
	Calcium Arsenate ^a	DCPA ^a	Benefin ^a	Bensulide ^a	Siduron	Terbutol ^a	Pronamide ^a	Oxadiazon ^a
<u>Number of treatments</u>								
<u>per year</u>								
Cool season	2	1	1	--	--	--	--	--
Warm season	2	1	1	--	--	--	--	--
TURFGRASS SITES ^c								
<u>Cool season</u>								
Bluegrass	X	X	X	X	X	X	--	X
Tall fescue	X	X	X	X	X	--	--	--
Fine-leaved fescue	X	--	--	X	X	X	--	--
Smooth brome grass	--	--	--	--	X	--	--	--
Perennial ryegrass	X	--	X	X	X	--	--	X
Orchardgrass	--	--	--	--	X	--	--	--
Bentgrass	X	--	--	X	X	X	--	--
Poa trivialis	--	--	--	X	--	--	--	--
Red top	--	X	--	X	X	--	--	--
<u>Warm season</u>								
Centipedegrass	--	X	X	X	--	X	--	--
Zoysiagrass	X	X	X	X	X	X	--	--
Bermudagrass	X	X	X	X	--	X	X	X
Bahiagrass	--	X	X	X	--	--	--	--
Carpetgrass	--	X	--	--	--	--	--	--
St. Augustine	-- ^d	X	X	X	--	X	--	X
Dichondra	-- ^d	--	--	X	--	X	--	--

^a For use on established turf only.

^b As determined by pest and geographic location.

^c Refer to "Alternatives" section of "Calcium Arsenate on Turf" previously in this chapter for more specific turf varieties and strains.

^d The Calcium Arsenate label specifically states, "Do not use on dichondra or St. Augustine lawns."

resume production (EPA, 1972a). Production ceased because of the financial investments necessary to meet OSHA workplace air standards, and uncertainty about continued registration because of current RPAR review (covered earlier in this chapter).

The same production situation is true of the other two registration holders--J & L Adikes and Los Angeles Chemical Company. They have not produced calcium arsenate for years. In both cases the companies have asked, or are in the process of asking, that their registrations be canceled for use of calcium arsenate on turf (Cummings, 1979; and Wackermann, 1979). There are at least two manufacturers, however, that are interested in this use of calcium arsenate (Alden, 1980; and Mitchell, 1980).

Loss of the use of calcium arsenate for Poa annua control might have involved considerable economic loss on the part of many golf courses in the past. It is estimated that 2,000 of the approximately 11,000 golf courses around the country used calcium arsenate to some extent. Some of these golf courses had been using calcium arsenate for as long as 20 years. It has been estimated that in the East, a typical golf course had spent about \$2,000 per year on calcium arsenate. In the West, in the first year or two, golf courses spent about \$4,500 per year and \$2,500 annually thereafter. Costs of calcium arsenate for Poa annua were probably higher in the Midwest.

Assuming an annual expenditure of about \$2,500 per year per course, the 2,000 courses spent on the order of \$5 million annually. The various golf courses across the country used calcium arsenate for varying periods of time, but if a nationwide average of about 7 years is assumed, then golf courses may have had \$35 million invested in a calcium arsenate Poa annua control program. To put this in perspective, however, it should be noted that annual golf course maintenance budgets are about \$150,000 apiece. The calcium arsenate program accounted for between 1% and 2% of the total expenditures on course maintenance (EPA, 1972a).

Assessing the economic impact of past loss of calcium arsenate in the present is not possible, inasmuch as there are alternatives available that were not in existence at the time calcium arsenate was used and calcium arsenate is no longer used on turf. The impact of the phytotoxicity of alternatives, however, is not easily defined in economic terms. Golf course turf is not a commercial crop, but, rather, is valued because of its esthetic and recreational qualities. Estimates of economic effects of lessened attractiveness or playability of golf courses are not available. There may be some economic loss associated with decreased quality of the turf itself. The magnitude of this potential loss is, however, unknown.

Calcium Arsenate—Slug and Snail Control

Current Use Analysis

Calcium arsenate is registered by EPA for 53 sites, including tree fruit, small fruit, vegetables, field crops, and non-crop areas for control of both slugs and snails. Table 39 shows a detailed listing of the registered sites along with a selection of the major registered alternative chemical controls for slugs and snails. The chemical metaldehyde is the most frequently appearing registered alternative, duplicating all 53 sites. Carbaryl is the next most frequently appearing chemical with registrations on about one-half (26 of 53) of the sites for which calcium arsenate is registered for slug or snail control.

Table 39.--EPA registration of calcium arsenate and selected alternative chemicals for slug and snail control

Site	Registered Chemicals						
	Calcium Arsenate	Metalddehyde	Carbaryl	Methoxychlor	Malathion	Methiocarb	Mexacarbate
<u>Tree Crops</u>							
Apples	X	X	X				
Apricots	X	X	X	X		X	
Avocados	X	X					
Cherries	X	X	X	X		X	
Grapefruit	X	X					
Lemons	X	X					
Nectarines	X	X	X				
Oranges	X	X					
Peaches	X	X	X	X		X	
Pears	X	X	X				
Plums	X	X	X	X		X	
<u>Small Fruit</u>							
Blackberries	X	X					
Boysenberries	X	X					
Loganberries	X	X					
Raspberries	X	X					
Strawberries	X	X					
<u>Vegetables and Field Crops</u>							
Asparagus	X	X	X				
Beans	X	X	X				
Blackeyed Peas	X	X					
Broccoli	X	X	X				
Brussels Sprouts	X	X	X				
Cabbage	X	X	X				
Cantalopes	X	X					
Carrots	X	X	X				
Cauliflower	X	X	X				
Celery	X	X					

Table 39.--EPA registration of calcium arsenate and selected alternative chemicals for slug and snail control--continued

Site	Registered Chemicals						
	Calcium Arsenate	Metaldehyde	Carbaryl	Methoxychlor	Malathion	Methiocarb	Mexacarbate
Collard	X	X					
Corn	X	X					
Cowpeas	X	X					
Cucumbers	X	X	X				
Eggplant	X	X	X				
Kale	X	X					
Kohlrabi	X	X					
Melons	X	X	X				
Mustard	X	X					
Onions	X	X					
Peppers	X	X	X				
Pumpkins	X	X					
Rutabagas	X	X					
Spinach	X	X	X				
Squash	X	X	X				
Tomatoes	X	X	X				
Turnips	X	X					
<u>Non-crop Sites</u>							
Commercial Inedible							
Outdoors	X	X					
Domestic Dwelling							
Outdoors	X	X	X			X	X
Flowering Plants	X	X	X			X	X
Greenhouses	X	X	X			X	
Lath Houses	X	X				X	
Lawns	X	X				X	
Non-crop Areas	X	X				X	X
Nurseries	X	X	X				X
Ornamental Plants		X	X	X			X
Terrestrial Structures	X	X					X

Source: EPA, 1976c.

Use of Calcium Arsenate and Alternatives

Information on the extent of use of calcium arsenate for slug and snail control is very limited. The Assessment Team could provide no information in this area. California does provide reports of calcium arsenate use by site within that State. Table 40 shows the reported use of calcium arsenate and metaldehyde, the major alternative, for the period 1975-1977. The distinctive feature of Table 40 is that both calcium arsenate and metaldehyde have their greatest usage in California on citrus crops.

Table 40.--Usage of calcium arsenate and metaldehyde on selected sites in California, 1975-1977^a

Site	1975		1976		1977	
	Calcium Arsenate	Metaldehyde	Calcium Arsenate	Metaldehyde	Calcium Arsenate	Metaldehyde
- - - - - Pounds Active Ingredient - - - - -						
Agencies, other	3,287	2,094	2,502	1,513	350	1,269
Avocado	338	249	262	245	--	19
Citrus	700	522	2	1	--	149
Citrus other	2,697	1,774	2,947	2,318	579	1,583
Lemon	2,004	3,005	1,118	2,881	333	2,414
Orange	1,042	2,359	2,082	3,177	878	4,570
Ornamentals	113	74	--	34	1	85
Other	617	2,312	759	2,656	not available	
Total	10,798	12,389	9,672	12,825	not available	

^a Source: California Dept. of Food and Agric.; 1975, 1976, and 1977.

Little inference can be drawn from the information reported by California. Calcium arsenate and metaldehyde may not be used solely for slug and snail control, because both chemicals are registered for other pests. Also, calcium arsenate and metaldehyde are formulated in combination for control of slugs and snails. Therefore, categorizing the use of these chemicals as either complementary or substitutes for one another cannot be done based on the available data.

The typical formulation of slug and snail bait contains 5% calcium arsenate and 2% metaldehyde. The bait substrate varies, depending on the product. Application rates range from 22.4 to 56.0 kg of bait per hectare (20 to 50 pounds of bait per acre). Either one or two applications may be made per season. This implies that

2 to 5 pounds active ingredient of calcium arsenate and 0.4 to 2 pounds active ingredient of metaldehyde are used on a treated acre per season.

Comparative Performance

Calcium arsenate is combined with metaldehyde in slug and snail baits at 5% and 2% active ingredient, respectively. This combination frequently provides mortalities in the range of 90%. Metaldehyde alone is recognized as effective in controlling slugs and snails when preparations containing 7 to 10% active ingredient are used (discussed previously in this chapter).

Methiocarb and methiocarb in combination with metaldehyde show promise as being as effective or more effective than the calcium arsenate/metaldehyde baits. Methiocarb, however, has only limited special local needs registrations at this time (discussed previously in this chapter).

Economic Impact Analysis

User Impacts.--Lack of data on the volume of calcium arsenate used for slug and snail control prevents a quantification of the total uses impacts should cancellation of this use occur. The need for slug or snail control on many of the crops for which calcium arsenate is registered is localized and/or temporal (previously discussed in this chapter).

For sites in some areas of California such as coastal counties or where sprinkler or drip irrigation is practiced, many growers must treat regularly for snail control. In typical years, data reported by the State of California indicate that about 10,000 to 12,000 pounds of calcium arsenate were applied to citrus for snail control (see Table 40). If all of this were for slug and snail control, then 5,000 to 6,000 acres could have been treated given an application rate of 2.0 pounds active ingredient per acre per season. In years when climatic conditions favor snail development, such as happened in 1978, approximately 11,000 acres were reported treated in one county (Riverside County) alone (Carman, 1979a). The extent to which citrus was treated for snails for all of California in 1978 is not available, but is obviously significantly higher than in average years.

The limited data available indicate that in typical years citrus growers might need to spend an additional 6.40 \$32.00 per acre on about 5,000 to 6,000 acres (3% of California citrus acreage). In 1977, the total cash costs for producing oranges in California were estimated to be \$1,291 per acre; adding depreciation and interest on investment gives an on-tree total production costs of \$2,930 per acre (Gustafson and Rock, 1977). If growers incurred a cost increase at the maximum estimate of \$32.00 per acre as a result of canceling calcium arsenate for slugs and snails on citrus, then this increase would represent 2.5% and 1.1% of total cash costs and total on-tree production costs, respectively. The total cost of production increase to California growers in typical years would be about 70,400 to \$176,000. In some years, the acreage requiring treatment would be significantly higher; thus the increase in treatment costs across all citrus growers would be higher.

The need for treating snails on citrus is generally a problem only in California; therefore, changes in production costs resulting from cancellation of calcium arsenate would be unlikely to affect total citrus supply or price in the United States. Affected growers would thus be unable to pass on all of the increased cost of production.

For commodities other than citrus, production cost increases would be expected to occur in the same range as found on citrus. Given the sporadic need for snail control on these other crops, again it is unlikely that all of the increased production costs could be passed on by affected growers.

Comparative Costs.--The typical bait formulation containing 5% calcium arsenate and 2% metaldehyde is estimated to cost \$27 per 100 pounds (Carman, 1979). The cost per treatment, assuming 20 to 50 pounds of bait per acre, would therefore be 5.40 to \$13.50. The season cost of treatment could be as high as 10.80 to \$27.00 per acre when two applications are necessary.

If metaldehyde alone was used in a bait formulation, then adequate control would be achieved if bait containing 7.5% active ingredient were used (Carman, 1979). The cost of a bait formulation containing 7.5% metaldehyde would be approximately \$59 per 100 pounds (Carman, 1979). Treatment cost would range from 11.80 to \$29.50 per treatment-acre or 6.40 to \$16.00 per treatment-acre higher than the combination with calcium arsenate. Cost per season using metaldehyde alone falls in the range of 11.80 to \$59.00 per acre. The increase in season treatment cost per acre would be 6.40 to \$32.00 over the cost of the calcium arsenate and metaldehyde combination.

Market and Consumer Impacts.--The limited extent to which individual crops rely on slug/snail control would indicate that production levels and prices for the several commodities involved should not be significantly affected.

Limitations of the Analysis

1. Detailed use pattern data were not available for calcium arsenate use on slug/snail control.

2. The assumption was made that the primary alternative chemical, metaldehyde, would be available in the volume needed to replace calcium arsenate, and that the price of the alternative would not change.

Calcium Arsenate—Fly Control

(No narrative, Summary on page 118.)

Summary of Economic Impact Analysis of Canceling Calcium Arsenate

Calcium Arsenate—Turf

A. USE:	Sold until 1977 for use on turfgrass sites.		
B. PLANTS CONTROLLED:	Crabgrass, annual bluegrass, chickweed		
C. ALTERNATIVES:	DCPA	siduron	oxadiazon
	benefin	terbutol	
	bensulide	pronamide	
<u>Non-Chemical alternatives:</u>	Hand pulling		

<u>Comparative efficacy:</u>	Alternatives are effectively in use in some situations. Calcium arsenate is not presently sold. Since 1977, the demand for the product has not resulted in its appearance in the market.
<u>Comparative costs:</u>	Not available.
<u>Comments:</u>	Not sold since 1977 because OSHA air standard regulations prevented production in U.S. and registrants are not importing.
D. EXTENT OF USE:	Quantity of residual stocks continues to be used.
E. ECONOMIC IMPACTS:	
<u>Users:</u>	Users depleting existing stocks.
<u>Market:</u>	Not marketed.
<u>Consumer:</u>	Not sold.
<u>Macroeconomics:</u>	None.
F. SOCIAL/COMMUNITY IMPACTS:	Not determined.
G. LIMITATIONS OF THE ANALYSIS:	Because this product has not been marketed in the U.S. since 1977, no actual prices could be obtained. Seven registered alternatives are available for all pests and on all sites previously controlled by calcium arsenate on turf. Most have some problems on some sites.
H. ANALYSTS AND DATE:	Robert O'Brien Economist EPA/EAB/BFSD OPP/OPTS Washington, D.C. Ray Stanton Economist USDA Washington, D.C. Dec. 1979

Calcium Arsenate—Slug and Snail Control

A. USE:	Calcium arsenate use to control slugs/snails on various crops.
B. MAJOR PESTS CONTROLLED:	Slugs and snails.

C. ALTERNATIVES:

Major registered chemicals:

Metaldehyde, carbaryl (pre-RPAR), methoxychlor, malathion, methiocarb, and mexacarbate.

Nonchemical controls:

Effective nonchemical control methods are not available.

Efficacy of alternatives:

Metaldehyde baits containing 7 to 10% active ingredient are equivalent to the commonly used calcium arsenate (5%) and metaldehyde (2%) combination baits.

Comparative Costs:

Use of baits containing 7 to 10% metaldehyde would increase production costs by 6.40 to \$32.00 per acre per season in comparison to calcium arsenate plus metaldehyde combination baits.

D. EXTENT OF USE:

Information on calcium arsenate use in slug/snail baits is not available for the total United States. Data for California show usage of about 10,000 to 12,000 pounds a.i. in the years prior to withdrawal from production on the part of formulators. Greatest usage in California was on citrus crops. The quantity of calcium arsenate used would be sufficient to treat about 5,000 to 6,600 acres annually in California. Climatic conditions sometimes greatly increase need for treatment.

E. ECONOMIC IMPACTS:

User:

Growers producing crops needing slug and snail control may occasionally incur higher production costs of 5.40 to \$32.00 per acre per season. Total impacts range over 70 to \$180 thousand for citrus in typical years.

Market/consumer:

Negligible.

Macroeconomic:

Negligible.

F. LIMITATIONS OF THE ANALYSIS:

1. Lack of total and detailed use pattern data.
2. It is assumed that the primary alternative, metaldehyde, would be available in sufficient quantities to replace calcium arsenate.

G. PRINCIPAL ANALYST AND DATE:

Gary L. Ballard
Economic Analysis Branch
OPP Environmental Protection Agency
Washington, D.C.
Jan. 1980

Calcium Arsenate—Fly Control

- A. USE: Previously used to control house flies in poultry operations. No calcium arsenate is currently being used or manufactured.
- B. INSECTS CONTROLLED: House flies.
- C. ALTERNATIVES:
- | | | |
|-------------------------------|------------|-----------------|
| <u>Chemical alternatives:</u> | Stirofos | Fenthion |
| | Naled | Malathion |
| | Dichlorvos | Chlorfenvinphos |
| | Dimethoate | Ronnel |
- Nonchemical alternatives: Mechanical controls include: 1) hauling manure to a suitable site on 3- to 4-day schedule or 2) maintaining moisture of < 25% to > 75% to prevent house fly larvae development.
- Comparative cost: Calcium arsenate was about 25% less expensive than alternatives when it was available.
- Comments: Not currently being used or manufactured. Calcium arsenate would likely be the most widely used compound for fly control in poultry operations if it were available. No buildup of resistance to calcium arsenate is known, whereas resistance to synthetic chemicals has already developed.
- D. EXTENT OF USE: Not known.
- E. ECONOMIC IMPACTS:
- | | |
|------------------------|-------|
| <u>User:</u> | None. |
| <u>Market:</u> | None. |
| <u>Consumer:</u> | None. |
| <u>Macroeconomics:</u> | None. |
- F. SOCIAL AND COMMUNITY IMPACTS: None.
- G. LIMITATIONS OF THE ANALYSIS: Current prices of calcium arsenate are not available as it is not being used or manufactured.
- H. ANALYST AND DATE: Walter L. Ferguson
ESCS
USDA
Washington, D.C.
Dec. 28, 1979

Lead Arsenate

Lead Arsenate—Growth Regulator

Standard lead arsenate has been used for several decades as a growth regulator on Florida grapefruit to bring about a lower level of acidity in the juice. It advances the beginning date for fresh grapefruit shipments from Florida by approximately 2 months.

The only known sites of application of lead arsenate are found in peninsular Florida, where 107,023 acres of grapefruit 7 years of age or older are growing (Florida Dept. of Agric. and Consumer Serv., 1978). Not all are sprayed in any 1 year. According to a USDA survey (Doane Agricultural Serv. Inc., 1978), only 37,591 acres were treated in 1977, or 35% of the total bearing Florida grapefruit acreage. Grapefruit trees are sprayed after bloom in the spring, over a period of approximately 2.5 months. Any grove worker probably works with As less than 1 week, although up to 50 days/year maximum is possible. There are no data on actual levels of exposure of either applicators or harvesting labor.

It is estimated that average application on the sprayed acreage is 1.30 pounds As per acre. Assuming average production of 34,898 pounds of fruit per acre and a maximum value of 0.07 ppm As in whole fruit, a total of 0.0024 pound As would be removed from each acre of grove in the harvesting operation. Residue on the fruit is reduced in concentration as well as in total amount by the multifold increase in fruit size after spraying and by the 3 to 4 month weathering period, including the normal Florida rainy season in the summer. Of the total residue on fruit, less than 10% is found in the juice or edible portion (Compton, 1976).

Supplies of lead arsenate have been somewhat limited in Florida since the announcement in 1975 of proposed OSHA occupational exposure standards (OSHA, 1978), which cut off former sources of supply of the dry powder product.

There are no alternative chemicals except other arsenicals. Of the others, calcium arsenate is equally effective on an equivalent As basis, could be manufactured and handled as safely, and would eliminate any question of lead residues. Calcium arsenate does not have EPA approval for use on grapefruit, although a petition asking for EPA approval was submitted through IR-4 January 23, 1976 (Compton, 1976).

Lead arsenate is used on grapefruit solely to lower the level of titratable acidity (mostly citric acid) in the juice of the mature fruit. This difference is easily detectable; the fruit tastes sweeter (less tart). Lowering acidity of the juice advances the time when fruit meets Florida legal maturity standards.

The effect has been known for at least 80 years. There was no commercial utilization of this information in any citrus-growing area until the advent of fruit quality regulations. In Florida, this occurred in the 1920's when production grew sufficiently large to justify fruit quality standards to protect consumers from shipment of immature fruit (Longfield-Smith, 1935).

Federal residue tolerances for spray materials including lead arsenate on citrus were set in the 1950's following passage of the Pesticide Chemicals Amendment (Miller Bill) to the Federal Food, Drug, and Cosmetic Act in 1954. The tolerance for citrus was set at 1 ppm lead, which still is in effect. Presumably, the tolerance was set on lead because of better analytical procedures. Although the Federal residue

standard applies to all citrus nationwide, lead arsenate may only be used on Florida grapefruit.

Florida began to regulate As use by passage of the Arsenical Spray Law in 1927 (Taylor, 1933), which prohibited the use of any As on citrus fruit either in spray or fertilizers. This law reinforces the first attempt at fruit quality regulation, which was (and still is, in part) based on a maturity test involving the ratio between total dissolved solids in juice and the acidity level (Soule, *et al.*, 1967). Attempts to enforce the Arsenical Spray Law led to court action in 1934, when an injunction was obtained prohibiting enforcement of the law with regard to grapefruit. In 1949, a revision and recodification of the Florida citrus fruit laws (Florida Citrus Code, of 1949) incorporated the grapefruit exemption into law and continued prohibition of As use on other citrus fruits. This law is actively enforced at the present time by the Florida State Department of Agriculture. Approximately 61,000 boxes (2,500 metric tons) of oranges and tangerines were withheld from utilization during the 1975-1976 crop season due to enforcement of the Arsenic Spray Law (Florida Dept. of Agric. and Consumer Serv., 1975-1976). Most violations are due to spray drift and spray operations in mixed plantings of grapefruit and other kinds of citrus. There is little interest in expansion of As use to other kinds of citrus fruit. Under the Florida Pesticide Application Act of 1974 as amended 1978, lead arsenate is a restricted pesticide, available for sale only to certified applicators holding restricted pesticide identification cards. Lead arsenate as a growth regulator appears in the registrations shown in Table 41.

Methods of Application

All lead arsenate used in grapefruit groves is applied as a foliar spray with conventional machines, the most common of which is the air-blast sprayer. Application by hydraulic sprayer, including multi-nozzle spray booms, is effective, but little used at present because of economic factors, primarily labor costs. Aerial application would probably be effective, but is not attractive due to the constraints of weight and problems of formulation. Soil applications of high amounts may bring about a detectable effect (Miller, *et al.*, 1933), but are not efficacious in bringing about the desired level of result and are wasteful of material and hence expensive.

The air-blast sprayer operator is a tractor driver whose sole function is to operate the tractor and sprayer at the prescribed speed and to be aware of any malfunctions that may occur in the equipment. The material for this sprayer is delivered by separate tank trucks. Each truckdriver places into the tank the prescribed amounts of various materials to be utilized in that particular application, while the tank is filled with water. The tank size is the same on the truck as on the air-blast sprayer. Depending on the distance of travel to obtain water and the level of concentrate application being utilized, one or possibly two trucks are required to service one air-blast sprayer. Mixing of the flowable lead arsenate is not likely to expose the mixing crew as much as the somewhat dusty, dry powder formerly used exclusively. In 1977, 99.3% of the material was applied from ground machines (Doane Agricultural Serv. Inc., 1978). The conventional air-blast sprayer most used is modified for this application only in respect to the number of nozzles operating to obtain the desired output in relation to speed of travel and tree size.

Dilution in the spray tank ranges from 4.0 to 12.5 pints of the 4-pound flowable lead arsenate per 500 gallons. This gives a concentration in the tank of 479 to 1,498 ppm PbHAsO_4 (101 to 315 ppm As) on a dilute spray basis. Various concentrate mixtures are also used, in which the concentration in the tank may be increased with a corresponding decrease in the number of gallons sprayed per acre. The amounts of

Table 41.--Companies with labels registered for lead arsenate use on grapefruit^a

EPA Registration Number	Company	Active Ingredient
		<u>Percent</u>
279-79	Niagara Chemical Co.	94.0
476-1084	Stauffer Chemical Co.	95.0
769-186	Woolfolk Chemical Works	96.0
2342-369	Kerr-McGee Chemical	96.0
6170-5	Lobel Corporation	96.0
9859-5667	Landia Chemical	52.0
9859-10408	Landia Chemical	32.8
35253-6036	Agra Chemical Sales	94.0

^a Source: Survey of Manufacturers, 1979.

the 4-pound-per-gallon flowable material are limited on the label to 10.8 pints per acre. Mature grapefruit trees are ordinarily sprayed on a dilute basis at the rate of 1,000 gallons, more or less. Groves with exceptionally large trees may require up to 1,500 gallons per acre.

Use Patterns and Efficacy

Lead arsenate is the only arsenical compound cleared for use on grapefruit to reduce acidity. Use of As on other citrus is illegal. To avoid excessive phytotoxicity, As should not be applied to trees less than 7 years of age. The most effective use of As is obtained by spraying within 1 to 6 weeks after bloom. Use 4.0 to 12.5 pints--4 pounds flowable lead arsenate per 500 gallons for white varieties and 4.0 to 6.0 pints for pink and red grapefruit. The lower amount is used for a high ratio of solids to acids in mid-season, and the higher amount for a high ratio in the early season (Knapp, 1979).

Mature grapefruit trees can usually be sprayed with 1,000 gallons of dilute spray mixture per acre. The maximum application would thus be 12.5 pounds lead arsenate per acre. According to a USDA survey, the average in 1977 was 6.2 pounds per acre (Doane Agricultural Serv. Inc., 1978).

Sprays are applied most commonly in the post-bloom period, when the developing fruit is between 1/2 and 1-1/2 inches in diameter, which occurs in April and May. Applications made after this period will be decreasingly effective.

Because timing of the application is not critical, the lead arsenate application is nearly always combined with application of other needed pesticides. The most

common time is the post-bloom period previously mentioned, at which time spraying is also carried out for the control of citrus rust mite, or melanose and other fungus diseases. If spraying is not conducted in the post-bloom period, As application is delayed until the next period of needed pest control, generally in June for control of rust mite, greasy spot disease, and scale insects.

Only one application is made each year, even though two produce an effect slightly greater than a single application. The additional effect is not sufficiently great to be economically justified.

The effect of As can be demonstrated in all citrus fruits (Longfield-Smith, 1935), but the magnitude is greater in the relatively low acid fruits such as mandarins and oranges. An application of As to a mandarin variety may bring about more than a 50% reduction in the titratable acid level of the juice, whereas an application made to grapefruit may produce only a 4 to 26% reduction.

The effect becomes progressively greater as the season advances. Harding and Fisher (1945) stated that a single spray reduced the acid level in white grapefruit by 4 to 9% in early season and up to 26% in late season. This advanced the time of legal maturity by 1 to 4 months. Deszyck and Ting (1958) showed that red and pink grapefruit varieties are more susceptible to the As effect than white varieties, leading to a different statement for the two groups in the Florida Citrus Spray Guide.

Exposure Analysis

The formulation most commonly used in Florida at the present time is a "flowable lead arsenate" containing 4 pounds of 96% active ingredient per gallon. This material is sold only in 5-gallon steel pails. Before the initiation of the OSHA air standards for As in 1975, however, the product was a wettable powder formulation that had been manufactured for decades, primarily for insecticidal use. In 1977, 45% of the As used was wettable powder and 54% was liquid (Doane Agricultural Serv. Inc., 1978). No special formulation of lead arsenate was ever prepared specifically for use on Florida grapefruit until the flowable product was offered for sale about 1976. This product is never mixed with other pesticides before being offered for sale.

Mixing of the flowable lead arsenate is not likely to expose the mixing crew as much as the somewhat dusty, dry powder formerly used exclusively; however, the mixer may spill or splash the concentrate on his hands during the tank charging process. The sprayer operator may be exposed to drift of the pesticide, but is almost invariably protected by a rigid canopy over the tractor which intercepts much of the drift. No other activities generally occur when grapefruit groves are being sprayed.

The user of lead arsenate in Florida grapefruit groves may include custom applicators, farmworkers, farmers, or certified applicators. The liquid formulation is distributed in 5-gallon containers with ample head-space, for stirring, and the potential for release of the liquid through spilling or splashing depends upon the care the mixer exercises.

No data on actual exposures of applicators or harvesters are available. To be realistic, these data can only be obtained during appropriate seasons of the year, namely, post-bloom for applicators, and fall for harvesters. Some data will be available by fall 1979.

Until actual data are available, some inferences may be suggested from the data of Wolfe, et al. (1972). Dermal, respiratory, and total exposure were determined for

11 pesticides during orchard spraying with air-blast sprayers in Washington. Formulation concentrations ranged from 0.03% to 0.12%. Recommended As concentrations would range from 0.01% to 0.03% in grapefruit spraying. Dermal exposures ranged from 0.10 mg/hr to 355 mg/hr. Respiratory exposures ranged from 0.01 mg/hr to 0.65 mg/hr. No systematic explanation could be given for the wide range of values obtained. Presumably As would fall into a similar highly variable pattern, but within a lower range than that shown by Wolfe, et al. (1972) for the higher percentage concentrations.

Estimates of exposure time to applicators involve numerous assumptions. The following assumptions are thought to be reasonable.

1. Lead arsenate is sprayed almost entirely in the post-bloom period, which might cover approximately 10 weeks or 50 working days. The absolute maximum acreage of sprayed grapefruit trees could not exceed the 107,023 total bearing acreage, but probably is nearer 38,000 acres annually (Doane Agricultural Serv. Inc., 1978). This is 4.9% of the total bearing acreage of 774,000 acres of citrus trees of all kinds in Florida (Florida Dept. of Agric. and Consumer Serv., 1978). The usual citrus production unit contains a mixture of all varieties and, consequently, the average spray operator would spend no more than 4.9% of his time in the post-bloom period spraying lead arsenate on grapefruit. This would amount to less than 3 days per year. We are not aware of a production organization in Florida that would have enough grapefruit to require any one spray operator to use As continuously for an entire post-bloom period of 50 working days.

2. Total worker-years' exposure to lead arsenate can be approximated using the assumptions of two 500-gallon tanks per acre (dilute basis), and thirty 500-gallon tanks per day. This amounts to 15 acres sprayed per day, or 2,533 worker-days maximum exposure for the entire 37,591 acres sprayed by the industry in 1977. A similar number of worker-days would be involved in the loading operation, but presumably the loader should receive only minimal exposure if carelessness on his part is prevented by supervision.

3. The size of typical treatment areas is probably not less than 5 acres, but may be much larger. It is unusual, however, for any one individual grapefruit grove to exceed 80 acres under ordinary circumstances in Florida.

Time required to spray out a 500-gallon tank of dilute spray materials in a typical air-blast sprayer operation is 10 to 12 minutes. Two to 5 additional minutes would be spent in the transfer operation from the truck servicing the sprayer to the sprayer tank. During the spraying operation, no time is spent on equipment maintenance and there is no need to change nozzles or do other related operations. If the sprayer or truck needs servicing or modification, it is ordinarily done by another crew.

Protective clothing is not ordinarily worn in the postbloom spraying period unless required by label instructions on materials used concurrently; however, virtually every tractor that pulls an air-blast sprayer has a rigid metal protective canopy over the driver which substantially minimizes his exposure to spray drift. Water is always available at the loading site for washing if the operator is inadvertently exposed.

Some assumptions may be used to approximate the exposure to consumers due to As use on Florida grapefruit. If 35% of the acreage is sprayed, then approximately 17.5 million of the 50 million total boxes would contain treated grapefruit. This amounts to 7.9 pounds of treated fruit in some channel of trade per capita. Inasmuch

as one-half of that weight would be juice which contains 0.03 ppm As, it follows that 0.054 mg/person/year, or 0.15 microgram/person/day, would be the average exposure of the consuming public due to this practice. This is insignificant relative to the average daily consumption of As in the United States in 1974, which was 16 micrograms (see Volume I, Chapter 4).

Attention must be directed to Table 12 in PD-1 (Federal Register, 1978). This is a presentation of the worst case situation, in which all commodities that have registrations for lead arsenate use are assumed to contain the maximum legal residue tolerance. The assumption is made that all citrus is sprayed with lead arsenate, even though it is illegal through State laws and U.S. label restrictions to apply As to any citrus in the United States except Florida grapefruit. As stated above, only 17,500,000 boxes, or 744,000 tons, of citrus are treated out of a total U.S. citrus crop of 15,273,000 tons, or less than 5% of the U.S. crop. None of the other crops listed is now sprayed with As. The exposures in Tables 9, 10, 11, and 12 of PD-1 are unrealistically high because As is no longer used on most of these crops.

The residue from canning plant operations is dried down to a high carbohydrate feed product commercially available under the name "dried citrus pulp." Over 1 million tons of dried citrus pulp are produced annually in Florida, although most of it comes from the processing of oranges. Residual solids (including pulp, peel, and seeds) from oranges and grapefruit are mixed in processing operation during a large portion of the year, thus diluting any As residue. Only at the beginning of the season could large amounts of dried citrus pulp be produced solely from treated grapefruit. Citrus pulp is primarily used as feed for dairy cattle in Florida, the northeastern United States, and Europe. Some assumptions can be applied to derive a reasonable estimate of the significance of As in animal products from this practice.

Fresh grapefruit peel has been estimated to contain 0.3 ppm As, and in the drying process can be expected to increase in concentration to 1.5 ppm As on a dry-weight basis. This is equivalent to 1.98 ppm As_2O_3 , which may be compared with the 3.5 ppm residue tolerance set on many raw agricultural commodities by the Food and Drug Administration many years ago. Dairy cattle might consume a total of 22 pounds of dried citrus pulp feed per day, and this would contain 15 mg As.

Marshall, *et al.* (1963) conducted a study to determine whether any change in levels of As in milk could be detected following continuous feeding of low levels to lactating cows. In an experiment that lasted 126 days, lactating cows were fed daily as much as 4.68 mg As per 100 pounds of body weight. These cows ranged from 820 to 1,040 pounds each, thus some of the cows in the high rate group may have received from 38.37 mg to 48.67 mg As per day for 126 consecutive days. Arsenic concentrations did not increase as a result of feeding and all samples analyzed had less than 0.05 mg As per liter in the milk (the minimum detection level).

If one assumes that these data are in fact representative and adequate, it seems clear that the amount of As in dried citrus pulp, as it is currently used, could not bring about a general increase in the level of As in milk.

Fate in the Environment

Based on the greatest As content of whole unwashed fruit of 0.07 ppm As and average yields, less than 0.2% of the total applied is removed with the crop. Arsenic is applied to the fruit when it is small in size, and it is weathered from the fruit surface during the usual rainy season from June to September when rainfall

averages more than 20 inches total. As a result, most of the As ends up in soil, although small amounts may be absorbed into the fruit.

The fate of As in soils is more extensively discussed elsewhere in this report (see Volume I, Chapter 4). Woolson (1969) determined total As on soils from two sites in central Florida that had a known history of relatively heavy As use in prior years. The highest As content reported was 7 ppm found in the 36- to 48-inch depth of a commercial grove. The soil type was an acid sand, low in exchange capacity, and heavily leached. This soil is typical in chemical and physical composition to a large proportion of the soils that are planted to grapefruit in Florida. Citrus trees root deeply (sometimes down to 20 ft) unless limited by water table or impervious layers. From these data and other inferences from Volume I, Chapter 4, it seems reasonable to believe that not much As will accumulate in the very sandy soils of Florida as a result of the present practice.

The extent to which As may be lost from Florida soils by volatilization or by leaching is not known (see Volume I, Chapter 4). Arsenic was not determined by Baker (1977) because the Florida Department of Environmental Regulation does not consider it to be a problem in Florida drinking water.

In summary, nearly all of the As used in spraying Florida's grapefruit groves remains in the groves, where it is subject to natural processes of sorption, erosion, leaching, and metabolism. Of the small amount carried from the grove in the fruit (not more than 3 grams/acre), more than 90% is found in the peel of the fruit. In normal utilization patterns, peel is either discarded by the fresh fruit consumer or incorporated into dried citrus pulp for cattle feed. The amounts of As found in dried grapefruit pulp feed are less than the amount required to bring about measurable increases of As in the milk of lactating cows fed an ordinary mixture of feeds.

Alternatives

There is no substitute for the element "arsenic" in obtaining the growth regulator effect of acid reduction in grapefruit. Any compound containing As will produce the effect, but no element or compound lacking As will do so. Numerous attempts have been made to find a substitute, but without success. The latest and current attempt to find a substitute for As is being conducted by Wilson (1978), Adjunct Associate Professor of the University of Florida (employed by the Scientific Research Department of the Florida Department of Citrus), who has tested several hundred compounds over each of the past 7 years.

Wilson has found several organic arsenical compounds to be effective in reducing grapefruit acidity, but these effects were smaller in proportion to As content than those obtained from lead arsenate. Organic arsenicals are under RPAR consideration by EPA.

Only two arsenical compounds have been given serious consideration as substitutes for lead arsenate. One of these was basic copper arsenate, which was manufactured for a short time by the Sherwin-Williams Company. The copper it contained had desirable fungicidal activity in addition to its effectiveness as a grapefruit sweetening agent (Deszyck, *et al.*, 1954). The As contained in this form is equivalent in effectiveness to that in lead arsenate. This product was discontinued by the manufacturer, presumably owing to lack of an adequate market.

Calcium arsenate, the other arsenical given serious consideration, was available, slightly more effective, less expensive, and higher in As content. Further, it does not contain lead. Calcium arsenate is an acceptable substitute for lead

arsenate as far as Florida grapefruit growers are concerned. Sufficient field testing has been accomplished to substantiate a recommendation by State agricultural workers.

In the interest of obtaining a registration for calcium arsenate as a substitute for lead arsenate on Florida grapefruit, a petition was submitted on January 23, 1976, to EPA (Compton, 1976). No action was taken on this petition (Pesticide Petition 6E1737 and Food Additive Petition 6H5153) until April 4, 1977, when EPA responded that the questions raised by the petition could not be completely evaluated until the Rebuttable Presumption Against Registration of inorganic arsenicals was resolved.

Lead Arsenate—Cherry Fruit Fly Control

Standard lead arsenate (10 to 15% dust or 94% wettable powder) acts as a stomach poison on western cherry fruit fly (*Rhagoletis indifferens* Curran) and is also labeled for use against codling moth, cankerworms, pearslug, and Syneta beetle on cherries and other deciduous tree fruit crops. Since the early 1950's, lead arsenate dusts and sprays were used effectively to prevent cherry fruit fly from ovipositing in ripening cherries prior to harvest. During a later period of usage (1960-1967), lead arsenate was principally applied by fixed-wing aircraft as a dust. About 1967 or 1968, aerial applicators became unable to purchase coverage from underwriters for lead arsenate applications, and alternative insecticides were resorted to, among them methoxychlor dust (organochlorine) and malathion (organophosphate) applied as an ultra low-volume (ULV) spray.

The Federal residue tolerance during the period that lead arsenate was used was set at 7 ppm on sweet cherries and remained in effect through at least 1975. The interval before harvest for the spray application was 30 days for fresh and 14 days for processing cherries. A 2-day preharvest interval for dust applications was established and permitted growers to apply the dust over the entire 4 to 6 week cherry fruit fly season. Results of residue analyses conducted by Oregon State University during the early 1950's on dust residues indicated that harvest samples of cherries receiving four applications of 15% dust, the last being made 1 day preharvest, were 1.6 ppm As--well under the official 7 ppm tolerance.

Methods of Application

The principal method of lead arsenate application was as a 15% dust applied by fixed-wing aircraft at 50 pounds per acre. Four to six applications were made, starting within 7 days of first adult fly emergence, which usually occurs in the The Dalles, Oregon area in mid-May. Applications were made each 7 to 10 days thereafter until harvest in late June to early July. This would amount to 30 pounds As per acre per year. Companies with registration for cherry fruit fly control are listed in Table 42.

Use Patterns and Efficacy

Because the tolerance for cherry fruit fly maggots in commercial sweet cherries is essentially zero, it is critical to start the fruit fly prevention program within 7 days of first adult emergence and continue on a regular schedule until harvest. At the first application, cherries are approximately 1/2-inch diameter and about 1-inch diameter at harvest. The aerial dust application was widely used in the Dalles area because it permitted rapid coverage of large acreages during the few short periods of ideal weather that occur in this windy area. Under the provisions of the Wasco County Pest Control District, all cherry trees in the area are to be

Table 42.--Companies with labels registered for lead arsenate use in cherry fruit fly control^a

EPA Registration Number	Company	Active Ingredient
		Percent
239-880	Chevron Chemical Co.	14.25
239-881	Chevron Chemical Co.	14.25
239-1288	Chevron Chemical Co.	47.50
239-1463	Chevron Chemical Co.	59.00
279-29	Niagara Chemical	94.0
279-46	FMC	96.0 (Basic)
359-41	Rhone-Poulenc	98.0
359-371	Rhone-Poulenc	90.5
476-374	Stauffer Chemical Co.	95.0
476-1186	Stauffer Chemical Co.	98.0
635-143	Central Chemical Corp.	98.0
1386-7	United Cooperatives	96.0
1871-8966	Farm Craft	15.0
1969-40	Parsons Chemical Works	97.0
2124-455	W. R. Grace	98.0
33955-31	PBI Gordon Corp.	98.0

^a Source: Survey of Manufacturers, 1979.

protected from cherry fruit fly infestation by applications of approved insecticides on a regular schedule during the fruit fly season.

Of the 7,500 acres of sweet cherries in the The Dalles area, it is estimated that all could receive one to possibly five annual applications, in the event cherry fruit fly develops resistance to the organophosphate insecticides presently used for control. Other cherry-growing acreages in the Milton-Freewater, Hood River, Willamette Valley, Oregon areas and Yakima Valley, Washington, areas would also use lead arsenate if resistance develops.

Exposure Analysis

Exposure to lead arsenate dust applications would be principally to applicator personnel (growers, aerial custom loaders, and pilots). Inasmuch as few orchard operations are conducted in cherry orchards prior to harvest, besides setting out sprinkler irrigation, orchard labor exposure to the residues on foliage or orchard floor would be confined to sprinkler-changing personnel. Pickers would be exposed to residues during harvest operations. Drift of the dust to surrounding residences could occur during applications made under windy conditions. No actual exposure data exist.

Fate in the Environment

Continual usage of lead arsenate dust on cherries in the The Dalles area prior to 1968 resulted in no observable phytotoxic problems to newly established cherry, apple, peach, or apricot plantings.

Lead arsenate dust is not as toxic to the beneficial predatory mite (Metaseiulus occidentalis (Nesbitt)) as certain organophosphate compounds such as azinphosmethyl, parathion, or diazinon, which are alternative registered fruit fly sprays. Malathion ULV, presently the most widely used preventative, has no known deleterious effect on predaceous mites.

A program utilizing some of the previously listed organophosphates has been observed to cause mid-season spider mite resurgences by reducing the predatory mite populations.

For a discussion on the fate of arsenate in the environment, see Volume I, Chapter 4.

Alternatives

Several alternatives to lead arsenate presently registered for cherry fruit fly control are: azinphosmethyl, carbaryl, diazinon, malathion, methiocarb, methoxychlor, parathion, and Perthane[®] (no longer available). Perthane[®] and carbaryl are candidates for RPAR. Methiocarb is extremely expensive (\$64.00/acre/application), and the other materials are organophosphate compounds, except methoxychlor. Although aerial application costs of lead arsenate would be twice as expensive as malathion, should cherry fruit fly develop resistance to the organophosphate insecticides the number of alternatives available would be limited to two compounds: methoxychlor and carbaryl. Both of these compounds have a very deleterious effect on beneficials, including mites.

Summary of Biological Analysis—Lead Arsenate

Growth Regulator

The use of lead arsenate as a growth regulator on grapefruit in Florida is one of the remaining agricultural uses of this pesticide. Current use patterns and legislation restrict application to part of the bearing grapefruit acreage in Florida only. Application rates are moderate and only one application is used per year. Opportunity for exposure to applicators is minimal. There are no alternatives to the use of lead arsenate for this purpose except other arsenicals. Calcium arsenate is a preferred substitute for lead arsenate, but is not registered for this use.

Cherry Fruit Fly Control

Lead arsenate is an effective insecticide for control of the cherry fruit fly. It is not currently being used because the organic alternatives are effective; however, continued registration for this use is desirable in case resistance to the organic insecticides develops.

Exposure would be minimal because it is aerially applied and few workers are in the orchard area during application. No environmental problems were observed from 15 years of previous use.

Economic Impact Analysis of Cancelling Lead Arsenate

Lead Arsenate—Growth Regulator

Current Use Analysis

Lead arsenate is used on grapefruit in Florida to reduce the acidity level in early-season grapefruit. This allows the maturity standard to be met earlier, so that grapefruit can be marketed as early as the first of September rather than the normal mid-November.

Lead arsenate was used on approximately 37,600 acres in Florida in 1977. This acreage represents about 35% of the total Florida grapefruit bearing acreage (discussed previously in this chapter).

The assumptions and procedures in this analysis are as follows:

1. The use of lead arsenate extends the shipping season for both pink and white fresh seedless Florida grapefruit by approximately 2-1/2 months. Marketing can start around September 1 rather than the normal mid-November, although considerable variability in starting date occurs from season to season depending on the specific growing season.

2. If lead arsenate is canceled, the level of production and quality of fruit is assumed to remain essentially unchanged. Fruit ripening and shipping in the absence of lead arsenate would return to the "normal" season (beginning mid-November).

3. The assumption is made that none of the grapefruit produced in untreated groves is marketed between September 1 and mid-November.

4. The data base used in the analysis covers the eight growing seasons from 1971 to 1972 through 1978 to 1979. The economic impact of a lead arsenate cancellation is estimated for the 1971 to 1972 to 1978 to 1979 seasons in order to demonstrate the variability in revenue impacts that may reasonably be expected to occur from one season to the next due to variations in fruit maturity patterns.

5. The assumption is made that in the absence of lead arsenate, the same total volume would be marketed fresh as was marketed when lead arsenate was available. Traditionally, the fresh market has absorbed all the fresh fruit that has met appropriate quality standards. It is reasonable to conclude that growers would attempt to maintain fresh quality sales in order to minimize the revenue effects of the shorter season caused by cancellation of lead arsenate. Some additional fruit may be diverted to processing, but this assumption appears to be appropriate based on the information available.

6. Prices used in the analysis for Florida Interior and Indian River white and pink grapefruit were as recorded by week and season (Tables 43 to 50; Growers Admin. Comm., 1972, 1972a, 1973, 1973a, 1974, 1974a, 1975, 1975a, 1976, 1976a, 1977, 1977a; Citrus Admin. Comm., 1978, 1978a, 1979, and 1979a).

7. Shipment data used in the analysis for Florida Interior and Indian River and Texas were as recorded by the Growers/Citrus Admin. Comm. (1972 to 1979).

8. Occasionally early season shipment data are reported without reported prices. In this event, the earliest reported price is used.

9. Cost of application will not be a consideration because the assumption is made that lead arsenate is always applied with other pesticides.

10. An ordinary least squares multiple regression technique is used to estimate the impact of a lead arsenate cancellation on the price of grapefruit.

11. The equation¹¹ used to estimate the impact on the price of Florida Indian River pink grapefruit is the following:

¹¹ This equation and the equations used to estimate the price of Indian River white seedless grapefruit and Interior pink and white seedless grapefruit were derived by Gary F. Fairchild. The equations used herein represent the third set of price-estimating equations developed during the course of the analysis. Previous equation sets were developed by Fairchild and Tilley (1979) and Luttner and Deluise (1979). The equation set reported here is used because of improved statistical significance and inclusion of additional relevant variables relative to the two previously developed equation sets.

Table 43.--Average weekly f.o.b. price of fresh Florida Interior and Indian River white and pink seedless grapefruit, 1971-1972 season^a

Week Ending	Interior		Indian River	
	White Seedless	Pink Seedless	White Seedless	Pink Seedless
Mo/Day/Yr	- - - - - Dollars Per 4/5-Bushel Carton - - - - -			
09/19/71	3.13	3.22	3.45	3.50
09/26/71	3.13	3.22	3.45	3.50
10/03/71	3.13	3.22	3.45	3.50
10/10/71	2.87	3.00	3.45	3.50
10/17/71	2.87	3.00	3.47	3.51
10/24/71	2.84	3.00	3.47	3.51
10/31/71	2.65	2.82	3.25	3.45
11/07/71	2.50	2.50	2.79	3.10
11/14/71	2.50	2.50	2.79	3.13
11/21/71	2.50	2.50	2.70	3.14
11/28/71	2.50	2.50	2.70	3.09
12/05/71	2.50	2.50	2.71	3.04
12/12/71	2.50	2.50	2.72	3.13
12/19/71	2.50	2.50	2.73	3.16
12/26/71	2.50	2.50	2.70	3.14
01/02/72	2.35	2.50	2.58	2.98
01/09/72	2.35	2.50	2.57	2.98
01/16/72	2.35	2.50	2.57	2.97
01/23/72	2.36	2.50	2.57	3.01
01/30/72	2.40	2.50	2.64	2.99
02/06/72	2.39	2.50	2.65	3.05
02/13/72	2.41	2.53	2.69	3.07
02/20/72	2.44	2.54	2.61	2.96
02/27/72	2.43	2.55	2.60	2.97
03/05/72	2.37	2.54	2.56	3.00
03/12/72	2.23	2.50	2.55	2.98
03/19/72	2.21	2.50	2.40	2.76
03/26/72	2.20	2.50	2.39	2.79
04/02/72	2.19	2.50	2.38	2.78
04/09/72	2.24	2.52	2.45	2.83
04/16/72	2.38	2.63	2.64	3.02
04/23/72	2.58	2.81	2.87	3.25
04/30/72	2.58	2.81	2.89	3.25
05/07/72	2.66	2.88	2.98	3.25
05/14/72	2.75	2.86	2.98	3.25
05/21/72	2.78	2.85	2.96	3.25
05/28/72	2.80	2.86	2.96	3.25
06/04/72	2.79	2.86	2.99	3.25
06/11/72	2.79	2.86	2.98	3.25
06/18/72	2.79	2.86	2.98	3.25

^a Source: Growers Admin. Comm. 1972a.

Table 44.--Average weekly f.o.b. price of fresh Florida Interior and Indian River white and pink seedless grapefruit, 1972-1973 season^a

Week Ending	Interior		Indian River	
	White Seedless	Pink Seedless	White Seedless	Pink Seedless
Mo/Day/Yr	Dollars Per 4/5-Bushel Carton			
09/03/72	3.50	4.60	4.00	5.25
09/10/72	3.50	4.60	4.00	5.25
09/17/72	3.50	4.60	4.00	5.25
09/24/72	3.50	4.60	4.00	5.25
10/01/72	3.50	4.60	4.00	5.25
10/08/72	3.50	4.60	4.00	5.25
10/15/72	3.50	4.16	4.00	5.49
10/22/72	3.23	3.40	3.48	4.24
10/29/72	2.77	2.98	3.23	4.25
11/05/72	2.50	2.74	2.68	3.53
11/12/72	2.39	2.62	2.70	3.53
11/19/72	2.38	2.63	2.71	3.31
11/26/72	2.40	2.51	2.72	3.52
12/03/72	2.41	2.67	2.70	3.41
12/10/72	2.39	2.75	2.74	3.36
12/17/72	2.41	2.75	2.60	3.32
12/24/72	2.30	2.55	2.50	3.84
12/31/72	2.30	2.53	2.50	2.85
01/07/73	2.35	2.53	2.58	2.91
01/14/73	2.35	2.57	2.58	2.85
01/21/73	2.35	2.54	2.58	2.92
01/28/73	2.40	2.62	2.63	3.05
02/04/73	2.40	2.62	2.65	3.08
02/11/73	2.40	2.62	2.68	3.17
02/18/73	2.39	2.72	2.68	3.15
02/25/73	2.40	2.63	2.69	3.14
03/04/73	2.39	2.62	2.69	3.14
03/11/73	2.39	2.50	2.69	3.15
03/18/73	2.39	2.50	2.68	3.15
03/25/73	2.40	2.41	2.68	3.15
04/01/73	2.40	2.40	2.69	3.15
04/08/73	2.40	2.40	2.69	3.15
04/15/73	2.40	2.50	2.70	3.20
04/22/73	2.40	2.55	2.70	3.22
04/29/73	2.43	2.57	2.73	3.25
05/06/73	2.45	2.60	2.73	3.23
05/13/73	2.46	2.60	2.76	3.28
05/20/73	2.56	2.79	2.75	3.27
05/27/73	2.63	2.78	2.94	3.27
06/03/73	2.73	2.76	2.95	3.25
06/10/73	1.75	2.76	3.08	3.27
06/17/73	2.71	2.79	3.07	3.27

^a Source: Growers Admin. Comm., 1973.

Table 45.--Average weekly f.o.b. price of fresh Florida Interior and Indian River white and pink seedless grapefruit, 1973-1974 season^a

Week Ending	Interior		Indian River	
	White Seedless	Pink Seedless	White Seedless	Pink Seedless
Mo/Day/Yr	- - - - - Dollars Per 4/5-Bushel Carton - - - - -			
09/09/73	5.65	5.85	4.40	4.60
09/16/73	5.65	5.85	4.40	4.60
09/23/73	5.65	5.85	4.40	4.60
09/30/73	5.65	5.85	4.40	4.60
10/07/73	4.20	4.45	4.40	4.60
10/14/73	2.90	3.00	3.40	3.60
10/22/73	2.70	3.00	3.00	3.50
10/29/73	2.70	2.95	2.95	3.45
11/05/73	2.55	2.95	2.95	3.45
11/12/73	2.40	2.95	2.95	3.45
11/19/73	2.40	2.90	2.65	3.45
11/26/73	2.40	2.90	2.70	3.25
12/03/73	2.40	2.80	2.50	3.30
12/10/73	2.40	2.80	2.65	3.25
12/17/73	2.40	2.83	2.69	3.42
12/24/73	2.40	2.83	2.71	3.38
12/31/73	2.40	2.83	2.71	3.38
01/07/74	2.45	2.83	2.71	3.37
01/14/74	2.44	2.80	2.64	3.26
01/21/74	2.40	2.75	2.60	3.32
01/28/74	2.38	2.71	2.58	3.02
02/04/74	2.30	2.59	2.54	2.99
02/11/74	2.31	2.57	2.59	3.06
02/18/74	2.30	2.58	2.57	3.00
02/25/74	2.31	2.59	2.59	2.98
03/04/74	2.26	2.46	2.43	3.03
03/11/74	2.16	2.34	2.48	2.96
03/18/74	2.10	2.32	2.45	2.80
03/25/74	2.10	2.32	2.45	2.80
04/01/74	2.10	2.32	2.45	2.80
04/08/74	2.07	2.33	2.33	2.80
04/15/74	2.11	2.37	2.38	2.88
04/22/74	2.14	2.48	2.50	2.91
04/29/74	2.14	2.48	2.50	2.91
05/06/74	2.12	2.48	2.60	3.04
05/13/74	2.28	2.57	2.75	3.05
05/20/74	2.32	2.63	2.75	3.06
05/27/74	2.57	2.75	2.90	3.20
06/03/74	2.57	2.75	2.90	3.20
06/10/74	2.57	2.75	2.78	3.00
06/17/74	2.56	2.75	2.68	2.85
06/24/74	2.55	2.75	2.72	2.90

^a Source: Growers Admin. Comm., 1974.

Table 46.--Average weekly f.o.b. price of fresh Florida Interior and Indian River white and pink seedless grapefruit, 1974-1975 season^a

Week Ending	Interior		Indian River	
	White Seedless	Pink Seedless	White Seedless	Pink Seedless
Mo/Day/Yr	- - - - - Dollars Per 4/5-Bushel Carton - - - - -			
09/01/74	2.65	3.00	2.90	3.50
09/08/74	2.65	3.00	2.90	3.50
09/15/74	2.65	3.00	2.90	3.50
09/22/74	2.65	3.00	2.90	3.50
09/30/74	2.65	3.00	2.90	3.50
10/07/74	2.60	3.00	2.83	3.50
10/14/74	2.57	3.00	2.79	3.50
10/21/74	2.57	2.85	2.71	3.15
10/28/74	2.57	2.85	2.65	3.20
11/04/74	2.59	2.85	2.69	3.20
11/11/74	2.55	2.83	2.70	3.31
11/18/74	2.57	2.84	2.70	3.31
11/25/74	2.57	2.85	2.70	3.31
12/02/74	2.57	2.85	2.70	3.30
12/09/74	2.55	2.81	2.69	3.44
12/16/74	2.56	2.83	2.57	3.44
12/23/74 ^b	2.57	2.81	2.64	3.44
12/30/74 ^b	0	0	0	0
01/06/75	2.56	3.00	2.68	3.50
01/13/75	2.60	3.03	2.65	3.50
01/20/75	2.64	3.08	2.71	3.50
01/27/75	2.62	3.08	2.72	3.50
02/03/75	2.61	3.07	2.71	3.50
02/10/75	2.63	3.07	2.70	3.50
02/17/75	2.62	3.07	2.72	3.50
02/24/75	2.59	3.07	2.84	3.50
03/03/75	2.59	3.06	2.95	3.73
03/10/75	2.54	3.23	2.82	3.86
03/17/75	2.66	3.36	2.98	4.01
03/24/75	2.71	3.49	3.07	3.99
03/31/75	2.69	3.48	3.03	3.97
04/07/75	2.67	3.49	3.00	4.00
04/14/75	2.66	3.49	3.05	3.99
04/21/75	2.57	3.48	3.94	4.06
04/28/75	2.83	3.73	3.00	4.09
05/05/75	2.86	3.72	3.07	4.09
05/12/75	2.93	3.72	3.08	4.08
05/19/75	2.92	3.72	3.10	4.08
05/26/75	3.10	3.97	3.40	4.36
06/02/75	3.21	3.97	3.47	4.36
06/09/75	3.22	3.97	3.55	4.40

^a Source: Growers Admin. Comm., 1975.

^b No prices reported due to Christmas shipping holiday.

Table 47.--Average weekly f.o.b. price of fresh Florida Interior and Indian River white and pink seedless grapefruit, 1975-1976 season^a

Week Ending	Interior		Indian River	
	White Seedless	Pink Seedless	White Seedless	Pink Seedless
Mo/Day/Yr	----- Dollars Per 4/5-Bushel Carton -----			
08/31/75	2.70	2.94	3.01	3.30
09/07/75	2.70	2.94	3.01	3.30
09/14/75	2.70	2.94	3.01	3.30
09/21/75	2.70	2.94	3.01	3.30
09/29/75	2.70	2.94	3.01	3.30
10/06/75	2.65	2.91	3.01	3.34
10/13/75	2.50	2.90	2.89	3.37
10/20/75	2.50	2.78	2.82	3.37
10/27/75	2.50	2.77	2.75	3.31
11/03/75	2.48	2.77	2.75	3.35
11/10/75	2.48	2.77	2.75	3.26
11/17/75	2.45	2.77	2.62	3.20
11/24/75	2.46	2.77	2.62	3.20
12/01/75	2.48	2.78	2.75	3.20
12/08/75	2.50	2.77	2.75	3.34
12/15/75	2.50	2.77	2.75	3.30
12/22/75	2.50	2.77	2.75	3.30
12/29/75	2.50	2.77	2.75	3.30
01/05/76	2.38	2.68	2.69	3.23
01/12/76	2.38	2.68	2.68	3.26
01/19/76	2.38	2.68	2.69	3.23
01/26/76	2.38	2.69	2.67	3.26
02/02/76	2.39	2.69	2.70	3.22
02/09/76	2.35	2.61	2.63	3.24
02/16/76	2.34	2.61	2.61	3.25
02/23/76	2.31	2.59	2.60	3.27
03/01/76	2.32	2.60	2.62	3.31
03/08/76	2.33	2.66	2.62	3.34
03/15/76	2.36	2.69	2.60	3.54
03/22/76	2.44	2.84	2.68	3.58
03/29/76	2.38	2.83	2.60	3.56
04/05/76	2.38	2.79	2.58	3.56
04/12/76	2.31	2.79	2.59	3.55
04/19/76	2.32	2.98	2.71	3.77
04/26/76	2.33	3.22	2.72	3.83
05/03/76	2.35	3.21	2.68	3.82
05/10/76	2.42	3.20	2.87	3.79
05/17/76	2.61	3.21	2.91	3.80
05/24/76	2.79	3.28	3.03	3.82
05/31/76	2.83	3.34	3.02	3.95
06/07/76	2.87	3.34	3.06	3.84
06/14/76	2.83	3.33	3.08	3.82

^a Source: Growers Admin. Comm., 1976.

Table 48.--Average weekly f.o.b. price of fresh Florida Interior and Indian River white and pink seedless grapefruit, 1976-1977 season^a

Week Ending	Interior		Indian River	
	White Seedless	Pink Seedless	White Seedless	Pink Seedless
Mo/Day/Yr	- - - - - Dollars Per 4/5-Bushel Carton - - - - -			
09/19/76	2.88	3.25	3.32	4.33
09/26/76	2.88	3.25	3.32	4.33
10/03/76	2.88	3.25	3.32	4.33
10/11/76	2.88	3.25	3.32	4.33
10/18/76	2.88	3.25	3.32	4.33
10/25/76	2.88	3.25	3.32	4.33
11/01/76	2.58	3.01	3.07	3.46
11/08/76	2.32	3.04	2.69	3.39
11/15/76	2.29	3.03	2.60	3.42
11/22/76	2.31	3.01	2.55	3.20
11/29/76	2.32	3.02	2.58	3.15
12/06/76	2.32	3.08	2.68	3.50
12/13/76	2.37	3.03	2.71	3.50
12/20/76	2.36	3.10	2.70	3.62
12/27/76	2.35	3.10	2.70	3.60
01/03/77	2.22	2.74	2.52	3.28
01/10/77	2.28	2.69	2.52	3.25
01/17/77	2.26	2.73	2.58	3.21
01/24/77	2.48	2.94	3.04	3.41
01/31/77 ^b	0	0	0	0
02/07/77	3.03	3.44	3.40	4.18
02/14/77	3.03	3.46	3.40	4.18
02/21/77	3.02	3.50	3.39	4.18
02/28/77	2.86	3.30	3.26	4.17
03/07/77	2.75	3.23	3.13	4.17
03/14/77	2.73	3.21	3.09	4.13
03/21/77	2.74	3.28	3.04	4.02
03/28/77	2.74	3.46	3.29	4.04
04/04/77	2.74	3.47	3.05	3.96
04/11/77	2.75	3.31	3.00	3.97
04/18/77	2.75	3.47	3.94	4.07
04/25/77	2.92	3.48	3.99	4.07
05/02/77	2.92	3.43	3.01	4.19
05/09/77	2.90	3.44	3.07	4.20
05/16/77	2.90	3.44	3.17	4.18
05/23/77	3.18	3.44	3.35	4.21

^a Source: Growers Admin. Comm., 1977.

^b No prices reported due to Christmas shipping holiday.

Table 49.--Average weekly f.o.b. price of fresh Florida Interior and Indian River white and pink seedless grapefruit, 1977-1978 season^a

Week Ending	Interior		Indian River	
	White Seedless	Pink Seedless	White Seedless	Pink Seedless
Mo/Day/Yr	- - - - - Dollars Per 4/5-Bushel Carton - - - - -			
10/02/77	2.90	3.95	3.30	4.60
10/09/77	2.90	3.95	3.30	4.60
10/17/77	2.90	3.95	3.30	4.60
10/24/77	2.90	3.95	3.30	4.60
10/31/77	2.90	3.85	2.45	4.50
11/07/77	2.55	3.40	2.95	4.20
11/14/77	2.45	3.20	2.70	3.75
11/21/77	2.45	2.95	2.80	3.70
11/28/77	2.45	2.90	2.85	3.75
12/05/77	2.50	2.90	2.85	3.85
12/12/77	2.50	3.00	2.95	3.75
12/19/77	2.50	3.00	3.00	3.80
12/26/77	2.50	3.00	3.00	3.85
01/02/78	2.50	3.00	3.00	3.85
01/09/78	2.55	3.10	2.90	3.60
01/16/78	2.55	3.05	2.88	3.47
01/23/78	2.53	3.03	2.90	3.61
01/30/78	2.55	3.04	2.92	3.59
02/06/78	2.55	3.05	2.93	3.63
02/13/78	2.55	3.05	2.90	3.55
02/20/78	2.54	2.87	2.89	3.53
02/27/78	2.55	2.80	2.90	3.56
03/06/78	2.54	2.78	2.88	3.50
03/13/78	2.55	2.75	2.85	3.50
03/20/78	2.47	2.70	2.77	3.46
03/27/78	2.36	2.56	2.68	3.43
04/03/78	2.30	2.50	2.70	3.40
04/10/78	2.30	2.53	2.72	3.50
04/17/78	2.30	2.60	2.63	3.42
04/24/78	2.50	2.78	2.73	3.40
05/01/78	2.53	2.79	2.75	3.41
05/08/78	2.56	2.77	2.86	3.35
05/15/78	2.61	2.92	2.85	3.45
05/22/78	2.62	2.94	3.01	3.51
05/29/78	2.81	3.04	3.06	3.55
06/05/78	2.89	3.07	3.19	3.63
06/12/78	2.86	3.11	3.31	3.70
06/19/78	3.25	3.22	3.62	3.95

^a Source: Citrus Admin. Comm., 1978.

Table 50.--Average weekly f.o.b. price of fresh Florida Interior and Indian River white and pink seedless grapefruit, 1978-1979 season^a

Week Ending	Interior		Indian River	
	White Seedless	Pink Seedless	White Seedless	Pink Seedless
Mo/Day/Yr	- - - - - Dollars Per 4/5-Bushel Carton - - - - -			
10/08/78	9.00	10.00	10.00	11.00
10/15/78	6.00	7.50	9.50	10.50
10/22/78	5.00	6.50	5.75	8.00
10/29/78	3.37	4.85	3.95	6.30
11/05/78	3.00	3.55	3.20	4.15
11/12/78	3.00	3.33	3.15	3.82
11/19/78	3.00	3.25	3.15	3.65
11/26/78	2.87	3.18	3.14	3.65
12/03/78	2.75	3.05	3.15	3.60
12/10/78	2.67	2.98	3.03	3.55
12/17/78	2.67	3.00	3.01	3.55
12/24/78	2.69	3.00	3.06	3.55
12/31/78	2.76	3.06	3.12	3.55
01/07/79	2.77	3.07	3.06	3.60
01/14/79	2.84	3.37	3.14	3.98
01/20/79	2.88	3.43	3.33	3.90
01/28/79	2.90	3.45	3.30	3.90
02/04/79	2.87	3.42	3.30	3.88
02/11/79	2.86	3.40	3.29	3.90
02/18/79	2.94	3.50	3.28	3.90
02/25/79	3.04	3.58	3.39	4.14
03/04/79	3.05	3.57	3.38	4.11
03/11/79	3.05	3.56	3.40	4.42
03/18/79	3.05	3.74	3.40	4.40
03/25/79	3.05	3.74	3.37	4.41
04/01/79	3.10	3.99	3.55	4.56
04/08/79	3.25	3.99	3.67	4.66
04/15/79	3.30	4.06	3.73	4.64
04/22/79	3.37	4.36	3.82	4.91
04/29/79	3.60	4.56	3.79	4.90
05/06/79	3.61	4.61	3.83	5.08
05/13/79	3.58	4.62	4.00	5.15
05/20/79	3.82	4.99	4.14	5.38
05/27/79	4.19	5.23	4.32	5.55
06/03/79	4.20	5.21	4.30	5.64
06/10/79	4.16	5.21	4.34	5.55

^a Source: Citrus Admin. Comm., 1979.

$$\begin{aligned}
\text{IRPSP} = & 3.379 - 0.0003942 \text{ IRS} + 0.0002655 \text{ INTS} - 0.0007674 \text{ TS} + 0.1002 \text{ S} + 0.3049 \text{ FR} \\
& (24.34) \quad (-2.424) \quad (1.273) \quad (-3.808) \quad (4.386) \quad (3.890) \\
& + 0.06957 \text{ SH} + 0.001838 \text{ D1L} - 0.002679 \text{ D2L} - 0.0001316 \text{ D3L} + 0.001171 \text{ D4L} \\
& (0.6999) \quad (0.4161) \quad (-0.6132) \quad (-0.0295) \quad (0.2489) \\
& + 0.005612 \text{ D5L} + 0.004712 \text{ D6L} + 0.004894 \text{ D7L} + 0.002512 \text{ D8L} \\
& (1.090) \quad (0.9127) \quad (1.031) \quad (0.5719) \\
& - 0.001606 \text{ D9L} \\
& (-0.3501)
\end{aligned}$$

$$R^2 = 0.4081$$

$$\text{Standard error} = 0.3288$$

Where:

IRPSP = Average weekly Florida Indian River pink seedless grapefruit price (dollars per 4/5 bushel carton).

IRS = Weekly Florida Indian River fresh grapefruit shipments (1,000 4/5 bushel cartons).

INTS = Weekly Florida Interior fresh grapefruit shipments (1,000 4/5 bushel cartons).

TS = Weekly Texas fresh grapefruit shipments (100 7/10 bushel cartons).

S = Time trend variable; 0 = 71-72; 1 = 72-73; 2 = 73-74; etc. This variable is a proxy to include exogenous influences such as changes in income or population.

FR = FREEZE 0-1 dummy variable (1 for all weeks after January 20, 1977). The January 1977 freeze in Florida caused a sudden dramatic increase in grapefruit prices which has continued up to the present.

SH = Shipping Holiday 0-1 dummy variable. A shipping holiday represents a suspension of shipments over the Thanksgiving and/or Christmas holidays by the Citrus Admin. Comm. The shipping holiday prevents a sudden glut of fruit on the market during these periods. Shipping holidays are not automatically imposed during these periods; for example, during the 1978-1979 season, shipments were suspended around Christmas (from December 21 to December 27), but a shipping holiday was not imposed at Thanksgiving (Growers/Citrus Admin. Comm., 1972a-1979a).

D1L = October crop estimate effect variable (1 multiplied by October Florida seedless grapefruit estimate for weeks from October to November estimate). The monthly crop estimate by the Florida Crop and Livestock Rep. Serv. (1971-1979) represents one of the few available measures of within-season supply. The monthly figure estimates the total season crop; by subtracting the quantity already picked, interested parties can determine how much fruit remains available for sale during that season. This information is used by chain store buyers, packinghouse operators, and other market agents to determine price. These variables

were included in the equations due to their theoretical importance to the grapefruit pricing mechanism. For a discussion of relevant but insignificant variables and the rationale for including such variables in analyses, see Rao and Miller (1971) and Kelejain and Oats (1974).

- D2L = November crop estimate effect variable (1 multiplied by November Florida seedless grapefruit estimate for weeks from November to December estimate).
- D3L = December crop estimate effect variable (1 multiplied by December Florida seedless grapefruit estimate for weeks from December to January estimate).
- D4L = January crop estimate effect variable (1 multiplied by January Florida seedless grapefruit estimate for weeks from January to February estimate).
- D5L = February crop estimate effect variable (1 multiplied by February Florida seedless grapefruit estimate for weeks from February to March estimate).
- D6L = March crop estimate effect variable (1 multiplied by March Florida seedless grapefruit estimate for weeks from March to April estimate).
- D7L = April crop estimate effect variable (1 multiplied by April Florida seedless grapefruit estimate for weeks from April to May estimate).
- D8L = May crop estimate effect variable (1 multiplied by May Florida seedless grapefruit estimate for weeks from May to June estimate).
- D9L = June crop estimate effect variable (1 multiplied by June Florida seedless grapefruit estimate for weeks from June to October estimate).

The numbers in parentheses are the t statistics associated with the respective coefficients in the regression equation.

12. The following equation is used to estimate the impact of a lead arsenate cancellation on the price of Florida Indian River white seedless grapefruit:

$$\begin{aligned} \text{IRWSP} = & 2.983 - 0.0003881 \text{ IRS} + 0.0001555 \text{ INTS} - 0.0004658 \text{ TS} + 0.03507 \text{ S} \\ & (34.76) \quad (-3.890) \quad (1.206) \quad (-3.738) \quad (4.180) \\ & + 0.2201 \text{ FR} + 0.02436 \text{ SH} + 0.00006765 \text{ DIL} - 0.005195 \text{ D2L} - 0.003299 \text{ D3L} \\ & (4.541) \quad (0.3963) \quad (0.02477) \quad (-1.923) \quad (-1.196) \\ & - 0.0004409 \text{ D4L} + 0.002691 \text{ D5L} + 0.0006798 \text{ D6L} + 0.0001409 \text{ D7L} \\ & (-0.1515) \quad (0.8453) \quad (0.2130) \quad (0.4800) \\ & + 0.003054 \text{ D8L} + 0.003661 \text{ D9L} \\ & (1.124) \quad (1.291) \end{aligned}$$

$$R^2 = 0.4519$$

$$\text{Standard error} = 0.2033$$

where:

IRWSP = Average weekly Florida Indian River white seedless grapefruit price
(dollar per 4/5-bushel carton).

Other variables are defined under equation (11).

The numbers in parentheses are the t statistics associated with the respective coefficients in the regression equation.

13. The following equation is used to estimate the impact of a lead arsenate cancellation on the price of Florida Interior pink seedless grapefruit:

$$\begin{aligned} \text{INTPSP} = & 2.974 - 0.0001979 \text{ IRS} + 0.00005013 \text{ INTS} - 0.00102 \text{ TS} + 0.073538 \text{ S} \\ & (26.17) \quad (-1.487) \quad (0.2936) \quad (-6.182) \quad (6.786) \\ & + 0.3466 \text{ FR} + 0.03237 \text{ SH} - 0.0002771 \text{ D1L} - 0.002809 \text{ D2L} - 0.000775 \text{ D3L} \\ & \quad (5.401) \quad (0.3977) \quad (-0.07664) \quad (-0.7853) \quad (-0.2123) \\ & + 0.002434 \text{ D4L} + 0.003718 \text{ D5L} + 0.001389 \text{ D6L} + 0.001794 \text{ D7L} \\ & \quad (0.6315) \quad (0.8819) \quad (0.3286) \quad (0.4614) \\ & + 0.002702 \text{ D8L} + 0.0001277 \text{ D9L} \\ & \quad (0.4728) \quad (0.3400) \end{aligned}$$

$$R^2 = 0.4848$$

$$\text{Standard error} = 0.2692$$

Where:

INTPSP = Average weekly Florida Interior pink seedless grapefruit price
(dollars per 4/5-bushel carton).

Other variables are defined under equation (11).

The numbers in parentheses are the t statistics associated with the respective coefficients in the regression equation.

14. The following equation is used to estimate the impact of a lead arsenate cancellation on the price of Florida Interior white seedless grapefruit:

$$\begin{aligned} \text{INTWSP} = & 2.803 - 0.0003829 \text{ IRS} + 0.00002665 \text{ INTS} - 0.0002887 \text{ TS} + 0.02961 \text{ S} \\ & (38.67) \quad (-4.510) \quad (0.2448) \quad (-2.744) \quad (-4.181) \\ & + 0.1961 \text{ FR} + 0.05086 \text{ SH} - 0.001885 \text{ D1L} - 0.006895 \text{ D2L} - 0.006188 \text{ D3L} \\ & \quad (-4.791) \quad (0.9800) \quad (-0.8174) \quad (-3.023) \quad (-2.658) \\ & - 0.002977 \text{ D4L} - 0.0006321 \text{ D5L} - 0.002681 \text{ D6L} - 0.002221 \text{ D7L} \\ & \quad (-1.211) \quad (-0.2351) \quad (-0.9948) \quad (-0.8962) \\ & + 0.001767 \text{ D8L} + 0.0005791 \text{ D9L} \\ & \quad (0.7705) \quad (0.2418) \end{aligned}$$

$$R^2 = 0.4938$$

$$\text{Standard error} = 0.1717$$

Where:

INTWSP = Average weekly Florida Interior white seedless grapefruit price
(dollar per 4/5-bushel carton).

Other variables are defined under equation (11).

The numbers in parentheses are the t statistics associated with the respective coefficients in the regression equation.

15. The explicit assumption is made in this analysis that the quantity that must be marketed in a later time period (fruit now shipped from September to mid-November) is distributed over the remaining months on the basis of the proportion of the quantity currently marketed in each month over the period November 15 to June 30.

16. Weekly f.o.b. prices are estimated for both the long marketing season (current situation) and the short marketing season (situation resulting from lead arsenate cancellation Tables 51 to 58).

17. Weekly revenues are calculated based on the above price estimates and the weekly shipments for the long and short marketing seasons.

18. Color distribution (white and pink) ratios for each season's shipments of Interior and Indian River grapefruit are applied to weekly Interior and Indian River shipments to estimate the weekly shipments of Interior white and pink grapefruit and Indian River white and pink grapefruit. This method is used because weekly shipment data are not reported by color type from the two production regions.

19. The 1977 lead arsenate use pattern (37,600 acres of Florida grapefruit treated) is assumed to be typical of annual usage.

Table 51.--Actual long-season shipments and estimated short-season shipments of Florida Interior and Indian River fresh grapefruit, 1971-72 season

Week Ending	Interior		Indian River		Texas ^a
	Long ^a	Short ^b	Long ^a	Short ^b	
Mo/Day/Yr	- - - - 1,000 4/5-Bushel Cartons - - - - -				1,000 7/10-Bushel Cartons
09/19/71	21	0	5	0	0
09/26/71	166	0	4	0	0
10/03/71	489	0	57	0	0
10/10/71	695	0	176	0	14
10/17/71	472	0	207	0	60
10/24/71	607	0	328	0	167
10/31/71	493	0	313	0	200
11/07/71	379	0	286	0	303
11/14/71	380	0	339	0	325
11/21/71	405	511	372	405	327
11/28/71	271	342	268	292	312
12/05/71	350	442	331	360	361
12/12/71	414	523	447	487	422
12/19/71	392	495	539	587	471
12/26/71	176	222	311	339	255
01/02/72	162	205	189	206	266
01/09/72	295	372	495	539	349
01/16/72	363	458	483	526	444
01/23/72	390	492	476	518	492
01/30/72	409	516	711	774	488
02/06/72	336	424	695	757	419
02/13/72	354	447	586	638	437
02/20/72	363	458	695	757	475
02/27/72	357	451	647	705	457
03/05/72	356	450	808	880	439
03/12/72	396	500	766	834	423
03/19/72	363	458	638	695	324
03/26/72	376	475	762	830	330
04/02/72	358	452	692	754	317
04/09/72	555	701	687	748	286
04/16/72	608	768	691	752	208
04/23/72	569	718	771	840	101
04/30/72	513	648	791	861	21
05/07/72	418	528	755	822	5
05/14/72	269	340	648	706	0
05/21/72	206	260	608	662	0
05/28/72	174	220	617	672	0
06/04/72	103	130	443	482	0
06/11/72	55	69	356	388	0
06/18/72	34	43	278	303	0

^a Growers Admin. Comm., 1972a.

^b Estimated by Economic Research Dept., Fla. Dept. of Citrus.

Table 52.--Actual long-season shipments and estimated short-season shipments of Florida Interior and Indian River fresh grapefruit, 1972-73 season

Week Ending	Interior		Indian River		Texas ^a
	Long ^a	Short ^b	Long ^a	Short ^b	
Mo/Day/Yr	- - - - 1,000 4/5-Bushel Cartons - - - - -				1,000 7/10-Bushel Cartons
09/03/72	4	0	1	0	0
09/10/72	15	0	1	0	0
09/17/72	39	0	19	0	0
09/24/72	64	0	32	0	0
10/01/72	169	0	97	0	26
10/08/72	305	0	122	0	67
10/15/72	503	0	211	0	124
10/22/72	619	0	303	0	168
10/29/72	741	0	421	0	181
11/05/72	513	0	383	0	286
11/12/72	507	0	330	0	373
11/19/72	423	0	611	0	303
11/26/72	299	378	373	418	165
12/03/72	396	500	537	602	418
12/10/72	399	504	459	515	473
12/17/72	400	505	539	605	360
12/24/72	212	268	386	433	313
12/31/72	170	215	215	241	282
01/07/73	283	357	513	575	247
01/14/73	249	314	617	692	147
01/21/73	466	588	639	717	462
01/28/73	370	467	599	672	461
02/04/73	440	556	911	1022	415
02/11/73	479	605	854	958	466
02/18/73	388	427	575	645	466
02/25/73	404	510	991	1111	186
03/04/73	417	527	892	1000	696
03/11/73	395	499	744	834	508
03/18/73	436	551	835	937	486
03/25/73	564	712	877	984	454
04/01/73	551	696	810	908	338
04/08/73	461	582	868	974	391
04/15/73	528	667	742	832	343
04/22/73	488	616	813	912	339
04/29/73	374	472	628	704	323
05/06/73	454	573	667	748	265
05/13/73	354	447	530	594	252
05/20/73	341	431	446	500	193
05/27/73	239	302	417	468	146
06/03/73	200	253	283	317	75
06/10/73	147	186	291	326	42
06/17/73	91	115	235	264	28

^a Growers Admin. Comm., 1973a.

^b Estimated by Economic Research Dept., Fla. Dept. of Citrus.

Table 53.--Actual long-season shipments and estimated short-season shipments of Florida Interior and Indian River fresh grapefruit, 1973-74 season

Week Ending	Interior		Indian River		Texas ^a
	Long ^a	Short ^b	Long ^a	Short ^b	
Mo/Day/Yr	- - - - 1,000 4/5-Bushel Cartons - - - - -				1,000 7/10-Bushel Cartons
09/09/73	10	0	6	0	0
09/16/73	2	0	16	0	0
09/23/73	19	0	21	0	0
09/30/73	77	0	46	0	1
10/07/73	290	0	86	0	0
10/14/73	600	0	211	0	22
10/22/73	723	0	401	0	32
10/29/73	617	0	416	0	151
11/05/73	493	0	515	0	249
11/12/73	451	0	445	0	262
11/19/73	375	0	348	0	304
11/26/73	213	275	333	373	259
12/03/73	310	401	455	509	387
12/10/73	406	525	494	553	452
12/17/73	358	463	523	586	517
12/24/73	232	300	408	457	387
12/31/73 ^c	6	8	4	4	76
01/07/74	262	339	585	655	462
01/14/74	288	373	568	636	372
01/21/74	295	382	403	451	472
01/28/74	343	444	553	619	431
02/04/74	256	331	608	681	414
02/11/74	195	252	367	411	421
02/18/74	389	503	819	917	595
02/25/74	366	473	756	846	435
03/04/74	304	393	686	768	455
03/11/74	279	361	697	780	414
03/18/74	315	407	707	792	380
03/24/74	330	427	832	931	353
04/01/74	336	435	815	912	323
04/08/74	350	453	787	881	211
04/15/74	370	479	899	1006	154
04/22/74	301	389	868	972	64
04/29/75	342	422	852	954	20
05/06/74	437	565	892	999	11
05/13/74	421	545	912	1021	5
05/20/74	405	524	912	971	0
05/27/74	324	419	820	918	0
06/03/74	175	226	408	457	0
06/10/74	107	138	315	353	0
06/17/74	91	118	254	284	0
06/24/74	1	1	2	2	0

^a Growers Admin. Comm., 1974a.

^b Estimated by Economic Research Dept., Fla. Dept. of Citrus.

^c No shipments reported due to Christmas shipping holiday.

Table 54.--Actual long-season shipments and estimated short-season shipments of Florida Interior and Indian River fresh grapefruit, 1974-75 season

Week Ending	Interior		Indian River		Texas ^a
	Long ^a	Short ^b	Long ^a	Short ^b	
Mo/Day/Yr	- - - - 1,000 4/5-Bushel Cartons - - - - -				1,000 7/10-Bushel Cartons
09/01/74	112	0	20	0	0
09/08/74	295	0	83	0	0
09/15/74	409	0	208	0	0
09/22/74	481	0	386	0	9
09/30/74	356	0	380	0	22
10/07/74	330	0	423	0	28
10/14/74	349	0	338	0	91
10/21/74	304	0	380	0	127
10/28/74	287	0	377	0	175
11/04/74	258	0	406	0	130
11/11/74	338	0	439	0	229
11/18/74	304	0	469	0	239
11/25/74	288	372	450	532	272
12/02/74	201	260	226	267	340
12/09/74	445	575	341	403	448
12/16/74	468	605	611	722	461
12/23/74	279	361	536	633	366
12/30/74 ^c	0	0	0	0	190
01/06/75	203	262	414	489	306
01/13/75	316	409	589	696	394
01/20/75	296	383	477	564	414
01/27/75	320	414	436	515	344
02/03/75	440	569	489	578	438
02/10/75	407	526	715	845	488
02/17/75	350	452	816	964	396
02/24/75	395	511	1121	1325	311
03/03/75	392	507	1106	1307	261
03/10/75	431	557	1067	1261	258
03/17/75	465	601	1129	1334	234
03/24/75	458	592	956	1130	110
3/31/75	477	617	946	1118	46
04/07/75	472	610	837	989	29
04/14/75	531	686	882	1042	14
04/21/75	373	482	643	760	7
04/28/75	340	440	753	890	0
05/05/75	248	321	603	713	0
05/12/75	184	238	485	573	0
05/19/75	125	162	360	425	0
05/26/75	117	151	287	339	0
06/02/75	109	141	197	233	0
06/09/75	107	138	141	167	0

^a Growers Admin. Comm., 1975a.

^b Estimated by Economic Research Dept., Fla. Dept. of Citrus.

^c No shipments reported due to Christmas shipping holiday.

Table 55.--Actual long-season shipments and estimated short-season shipments of Florida Interior and Indian River fresh grapefruit, 1975-76 season

Week Ending	Interior		Indian River		Texas ^a
	Long ^a	Short ^b	Long ^a	Short ^b	
Mo/Day/Yr	- - - - 1,000 4/5-Bushel Cartons - - - - -				1,000 7/10-Bushel Cartons
08/31/75	48	0	0	0	0
09/07/75	178	0	37	0	0
09/14/75	423	0	242	0	0
09/21/75	443	0	357	0	0
09/29/75	450	0	414	0	15
10/06/75	305	0	405	0	100
10/13/75	309	0	538	0	167
10/20/75	315	0	620	0	255
10/27/75	247	0	599	0	305
11/03/75	246	0	413	0	409
11/10/75	278	0	462	0	326
11/17/75	274	0	413	0	315
11/24/75	276	343	559	653	368
12/01/75	180	223	290	399	383
12/08/75	475	590	540	630	536
12/15/75	483	599	651	760	584
12/22/75	314	390	668	780	344
12/29/75	94	117	131	153	204
01/05/76	176	218	309	361	335
01/12/76	333	413	795	928	539
01/19/76	360	447	625	730	541
01/26/76	432	536	897	1047	562
02/02/76	352	437	717	837	432
02/09/76	416	516	753	879	542
02/16/76	382	474	842	983	592
02/23/76	362	449	812	948	549
03/01/76	369	458	674	787	524
03/08/76	426	529	943	1101	569
03/15/76	453	562	927	1082	483
03/22/76	450	558	980	1144	424
03/29/76	407	505	941	1099	429
04/05/76	421	523	983	1148	409
04/12/76	413	513	859	1003	343
04/19/76	486	603	955	1115	349
04/26/76	389	483	870	1016	209
05/03/76	341	423	768	897	124
05/10/76	342	424	662	773	56
05/17/76	250	310	546	637	41
05/24/76	197	244	537	627	17
05/31/76	156	194	321	375	0
06/07/76	106	132	199	232	0
06/14/76	90	112	164	191	0

^a Growers Admin. Comm., 1976a.

^b Estimated by Economic Research Dept., Fla. Dept. of Citrus.

Table 56.--Actual long-season shipments and estimated short-season shipments of Florida Interior and Indian River fresh grapefruit, 1976-77 season

Week Ending	Interior		Indian River		Texas ^a
	Long ^a	Short ^b	Long ^a	Short ^b	
Mo/Day/Yr	- - - - 1,000 4/5-Bushel Cartons - - - - -				1,000 7/10-Bushel Cartons
09/19/76	7	0	0	0	0
09/26/76	124	0	1	0	1
10/03/76	372	0	43	0	1
10/11/76	634	0	182	0	5
10/18/76	828	0	323	0	25
10/25/76	696	0	709	0	107
11/01/76	542	0	699	0	134
11/08/76	540	0	610	0	134
11/15/76	440	0	485	0	407
11/22/76	387	541	575	668	257
11/29/76	187	261	268	311	235
12/06/76	470	657	557	647	525
12/13/76	608	850	628	729	426
12/20/76	353	493	620	720	497
12/27/76	149	208	267	310	257
01/03/77	144	201	434	504	133
01/10/77	309	432	639	742	211
01/17/77	303	424	705	819	449
01/24/77	350	489	849	986	315
01/31/77 ^c	0	0	0	0	565
02/07/77	154	215	477	554	526
02/14/77	402	562	906	1052	405
02/21/77	318	444	708	822	497
02/28/77	275	384	910	1057	300
03/07/77	291	407	779	904	490
03/14/77	315	440	897	1041	489
03/21/77	262	366	883	1025	445
03/28/77	228	319	809	939	301
04/04/77	243	340	802	931	424
04/11/77	190	266	663	770	408
04/18/77	122	171	668	776	402
04/25/77	71	99	600	697	303
05/02/77	131	183	578	671	341
05/09/77	36	50	435	505	271
05/16/77	12	17	142	165	239
05/23/77	25	35	99	115	0

^a Growers Admin. Comm., 1977a.

^b Estimated by Economic Research Dept., Fla. Dept. of Citrus.

^c No shipments reported due to embargo following January 18-20 freeze.

Table 57.--Actual long-season shipments and estimated short-season shipments of Florida Interior and Indian River fresh grapefruit, 1977-78 season

Week Ending	Interior		Indian River		Texas ^a
	Long ^a	Short ^b	Long ^a	Short ^b	
Mo/Day/Yr	- - - - 1,000 4/5-Bushel Cartons - - - - -				1,000 7/10-Bushel Cartons
10/02/77	44	0	13	0	1
10/09/77	306	0	51	0	12
10/17/77	519	0	246	0	28
10/24/77	727	0	421	0	51
10/31/77	638	0	653	0	79
11/07/77	541	0	444	0	113
11/14/77	424	0	401	0	154
11/21/77	422	0	522	0	185
11/28/77	176	224	287	326	324
12/05/77	491	625	471	536	311
12/12/77	550	700	631	718	491
12/19/77	435	554	678	771	426
12/26/77	193	246	387	440	320
01/02/78	143	182	283	322	274
01/09/78	228	290	555	631	313
01/16/78	319	406	567	645	510
01/23/78	297	378	723	822	423
01/30/78	313	398	672	764	295
02/06/78	358	456	674	767	510
02/13/78	367	467	754	858	511
02/20/78	426	542	773	879	562
02/27/78	352	448	802	912	482
03/06/78	409	521	740	842	485
03/13/78	453	577	740	842	524
03/20/78	404	514	742	844	461
03/27/78	342	435	960	1092	494
04/03/78	390	496	589	670	410
04/10/78	376	479	758	862	484
04/17/78	402	512	767	872	420
04/24/78	373	475	750	853	417
05/01/78	372	474	520	592	296
05/08/78	337	429	456	519	313
05/15/78	298	379	460	523	103
05/22/78	322	410	457	520	121
05/29/78	214	272	315	358	10
06/05/78	141	179	219	249	5
06/12/78	96	122	279	317	0
06/19/78	66	84	244	278	0

^a Citrus Admin. Comm., 1978a.

^b Estimated by Economic Research Dept., Fla. Dept. of Citrus.

Table 58.--Actual long-season shipments and estimated short-season shipments of Florida Interior and Indian River fresh grapefruit, 1978-79 season

Week Ending	Interior		Indian River		Texas ^a
	Long ^a	Short ^b	Long ^a	Short ^b	
Mo/Day/Yr	- - - - 1,000 4/5-Bushel Cartons - - - - -				1,000 7/10-Bushel Cartons
10/08/78	37	0	55	0	5
10/15/78	411	0	216	0	14
10/22/78	523	0	495	0	86
10/29/78	601	0	750	0	170
11/05/78	523	0	650	0	222
11/12/78	465	0	621	0	400
11/19/78	386	276	770	509	338
11/26/78	278	346	369	425	348
12/03/78	413	517	429	495	496
12/10/78	551	689	579	666	679
12/17/78	452	564	659	759	622
12/24/78	202	251	517	595	412
12/31/78	118	148	398	457	224
01/07/79	302	378	470	542	339
01/04/79	394	492	819	944	151
01/20/79	374	467	781	899	22
01/28/79	428	534	863	994	267
02/04/79	387	482	881	1015	217
02/11/79	435	544	971	1117	241
02/18/79	468	585	900	1037	228
02/25/79	441	550	989	1139	179
03/04/79	481	601	982	1132	152
03/11/79	485	605	1110	1278	111
03/18/79	520	648	1015	1171	37
03/25/79	450	562	932	1075	8
04/01/79	433	539	912	1052	14
04/01/79	535	669	937	1080	12
04/15/79	480	600	996	1149	9
04/22/79	446	558	677	780	0
04/29/79	423	529	610	704	0

^a Citrus Admin. Comm., 1979a.

^b Estimated by Economic Research Dept., Fla. Dept. of Citrus.

Use Impacts

Current and Alternative Programs.--There is at the present time no alternative chemical registered for use as an acidity-reducing growth regulator on Florida grapefruit. In the arsenical group of chemicals, calcium arsenate is another potential alternative, although it has not been registered for this particular use. Apparently calcium arsenate would be as effective as lead arsenate and would involve a similar volume of active ingredient (discussed previously in this chapter).

In the event that calcium arsenate were not registered for use on Florida grapefruit, growers would be left without any replacement for lead arsenate. Growers would be forced to sustain the losses associated with the shortened marketing season.

Impact on Production Costs.--The impact on the cost of production will be analyzed under the assumption that calcium arsenate will not be available as an alternative if lead arsenate is banned from use. According to a 1978 USDA pesticide usage survey, the average quantity of lead arsenate applied per acre is 6.188 pounds (USDA, 1978a). This material is 96% active ingredient, however, which means that approximately 5.94 pounds of active ingredient are used per acre. The average price paid by growers for lead arsenate is \$5.35 per gallon (Mitchell, 1979). A gallon contains 3.84 pounds of active ingredient. Thus, the price per pound of active ingredient is approximately \$1.39. The materials cost per acre is approximately \$8.26. In the event of a cancellation of lead arsenate, this production cost would not be incurred by growers.

In 1977 the estimated extent of use was 37,591 acres in Florida (USDA, 1978a). At a cost per acre of \$8.26, the approximate total outlay made by Florida growers for lead arsenate is approximately \$310,500 annually. In the event that lead arsenate were canceled, this figure would represent a reduction in production cost outlays made by Florida grapefruit growers. Cost of application can be ignored because lead arsenate is nearly always applied with other pesticides (discussed previously in this chapter).

Impact on Production and Marketing.--As indicated above, a cancellation of lead arsenate would shorten Florida grapefruit growers marketing season. The quantity of the annual crop now marketed over the period September 1 to November 15 would have to be marketed from mid-November to the end of June.

Both white and pink Florida grapefruit from the Interior and Indian River marketing districts would be similarly affected by the cancellation of lead arsenate. For Florida Interior grapefruit, an average of 3.607 million 4/5-bushel cartons were marketed prior to mid-November over the past eight seasons. This represents 27.8% of the average total fresh Florida grapefruit shipments during the 1971-1972 through 1978-1979 seasons (Table 59). This quantity represents the additional amount of the annual Florida Interior fresh grapefruit crop that would be marketed in the remainder of the season (post mid-Nov.) if lead arsenate were no longer available for use.

For Florida Indian River grapefruit, the total quantity marketed prior to mid-November averaged 2.959 million 4/5-bushel cartons during the 1971-1972 through the 1978-1979 seasons (Table 59). This represents an average 13.9% of total Florida shipments per season. This percentage represents the additional portion of Florida Indian River fresh grapefruit crop that would be marketed after mid-November if lead arsenate were withdrawn from use.

Changes in Florida Fresh Grapefruit Revenues.--A lead arsenate cancellation would affect the weekly prices and shipment volumes of both white and pink fresh

Table 59.--Volume and percent of Florida Interior and Indian River fresh grapefruit shipments marketed prior to mid-November 1971-72 through 1978-79 seasons^a

Season	Interior		Indian River		Total Florida	
	<u>1,000 Cartons</u>	<u>Percent</u>	<u>1,000 Cartons</u>	<u>Percent</u>	<u>1,000 Cartons</u>	<u>Percent</u>
1971-72	3,702	26.3	1,715	8.9	5,417	16.2
1972-73	3,902	26.3	2,531	12.2	6,433	18.0
1973-74	3,657	29.3	2,511	12.0	6,168	18.4
1974-75	3,823	29.3	3,909	18.2	7,732	22.4
1975-76	2,342	24.1	4,087	16.7	7,329	19.4
1976-77	4,183	39.8	3,502	16.1	7,235	24.6
1977-78	3,621	27.3	2,751	13.8	6,372	19.2
1978-79	2,725	19.9	3,117	13.2	5,842	15.7
Average	3,607	27.8	2,959	13.9	6,566	19.2

^a Source: Calculated from Growers/Citrus Admin. Comm., 1972 to 1979.

Florida grapefruit from the Interior and Indian River marketing districts. Industry f.o.b. revenues and the incomes of growers of these commodities would thus be affected. Inasmuch as changes in f.o.b. prices and revenues are generally reflected directly in changes in grower level prices and revenue, it is appropriate to assume that changes in f.o.b. revenue resulting from a lead arsenate cancellation would be passed back to the grapefruit grower.¹² An assessment of this impact will be made by estimating the weekly f.o.b. prices that reflect both the "long marketing season" and the "short marketing season" for Interior white and pink and Indian River white and pink grapefruit (Tables 51 to 58).

By combining the weekly price estimates for the "long" and "short" marketing season with the actual long marketing season and the estimated short marketing season weekly shipments, weekly revenues were estimated for the "long" and "short" seasons. Changes in these gross revenues represent the impact of a lead arsenate cancellation on the Florida grapefruit industry.

Table 60 shows the estimates of gross revenues for the four fresh grapefruit categories under the assumption of a "long marketing season" and a "short marketing season" for the 1971-1972 through the 1978-1979 seasons. The average estimated annual revenue for the "long marketing season" is \$100.8 million. This estimate is based on the assumption that Florida Interior and Indian River white and pink grapefruit growers have the benefit of lead arsenate. The average estimated annual revenue for the "short marketing season" is \$94.8 million. This estimate is based on the assumption that Florida Interior and Indian River grapefruit white and pink grapefruit growers are not able to use lead arsenate and that the commodity cannot be marketed before mid-November. Thus, the average projected loss in annual revenue to growers of fresh Florida white and pink seedless grapefruit from the Interior and

¹² Growers tend to be residual claimants with respect to price and revenue when their fruit is sold through cooperatives and participation plans. Grower prices reflect f.o.b. prices less costs of picking, hauling, packing, and selling.

Table 60.--Estimated impact on Florida fresh grapefruit revenues of a ban on lead arsenate measured at the f.o.b. level, 1971-72 through 1978-79 seasons

Season	Long Marketing Season					Shortened Marketing Season					Revenue Change
	Interior		Indian River		Total Florida	Interior		Indian River		Total Florida	Total Florida
	White	Pink	White	Pink		White	Pink	White	Pink		
<hr style="border-top: 1px dashed black;"/> <div>1,000 Dollars</div> <hr style="border-top: 1px dashed black;"/>											
1971-72	19,230	21,930	27,048	22,046	90,254	17,584	19,862	26,698	21,592	85,737	4,517
1972-73	18,530	24,552	26,882	25,601	95,564	16,963	22,293	26,247	24,767	90,270	5,294
1973-74	15,842	21,410	28,190	26,909	92,351	14,177	19,042	27,584	26,074	86,877	5,474
1974-75	16,253	23,675	29,611	28,508	98,047	14,615	20,831	28,256	26,653	90,355	7,692
1975-76	18,526	22,439	36,052	28,852	105,869	16,612	19,730	33,715	26,541	96,597	9,272
1976-77	13,635	19,897	29,530	24,391	87,451	11,225	16,078	28,668	23,369	79,340	8,111
1977-78	24,609	22,229	37,667	24,035	108,539	22,334	20,067	36,489	23,189	102,079	6,460
1978-79	16,651	27,598	41,506	42,896	128,651	15,501	27,526	41,170	42,775	126,971	1,680
Total	143,276	183,730	256,486	223,238	806,726	129,011	165,429	248,827	214,960	758,226	48,500
Average	17,910	22,966	32,061	27,905	100,841	16,126	20,679	31,103	26,870	94,778	6,063

Indian River marketing districts would be approximately \$6.1 million. Table 61 gives the color distribution of grapefruit from the two major producing regions.

Table 61.--Color distribution of Florida Indian River and Interior fresh seedless grapefruit shipments, season averages 1971-72 through 1978-79^a

Season	Indian River ^b		Interior ^b	
	Pink	White	Pink	White
	- - - - - Percent - - - - -			
1971-72	43	57	53	47
1972-73	39	61	49	51
1973-74	38	62	48	52
1974-75	36	64	47	53
1975-76	40	60	52	48
1976-77	35	65	50	50
1977-78	46	54	56	44
1978-79	44	56	56	44

^a Source: Growers Admin. Comm., 1972a to 1977a; Citrus Admin. Comm., 1978a, 1979a.

^b Ratios used to calculate weekly white and pink shipments from the Interior and Indian River marketing districts for each season.

Over the eight seasons considered, the loss in revenue varied from a low of \$1.7 million in 1978-1979 to a high of \$9.3 million in 1975-1976 (Table 62). The degree of variation in the impact of a lead arsenate cancellation is associated with the particular growing conditions of a given season and the amount of fruit which is shipped prior to mid-November (Table 59).

Net Producer Level Impact.--The net impact, at the producer level, of a lead arsenate cancellation is estimated by taking into account both the reduction in grower revenue and the change in production cost that would occur if the chemical were no longer available. As noted above in the section on production cost, the reduction in production cost would be approximately \$8.27 per acre. If lead arsenates were canceled, this cost would not be incurred by growers. Production costs would be reduced by this amount because no alternative material is currently registered for use by growers.

The approximate total outlay made by Florida growers for lead arsenate is \$0.31 million. The estimated average reduction in annual f.o.b. revenue would be approximately \$6.06 million, and therefore the net negative impact on Florida growers after taking the reduction in production cost outlay into account is approximately \$5.75 million (Table 63) or about \$153 per affected acre.

The loss in gross f.o.b. revenue that would be incurred by Florida grapefruit growers can be measured as a percent of the total f.o.b. value of Florida fresh grapefruit (Table 62). For the 1971-1972 through 1978-1979 seasons, the estimated average loss in f.o.b. gross revenue of \$6.06 million is 5.8% of the total estimated f.o.b. value for fresh Florida grapefruit of \$104.3 million. The average f.o.b. revenue for Florida seedless grapefruit approximated \$1,100 per acre during this

Table 62.--Estimated gross f.o.b. revenue loss from lead arsenate cancellation as a percent of total f.o.b. value of Florida fresh grapefruit, 1971-72 through 1978-79

Season	F.o.b. Value Florida Fresh Grapefruit ^a	Estimated Revenue Loss	Loss as Percent of Total Value
	- - - - 1,000 Dollars - - - -		Pct
1971-72	87,800	4,517	5.1
1972-73	90,427	5,294	5.9
1973-74	95,500	5,474	5.7
1974-75	108,300	7,692	7.1
1975-76	111,000	9,272	8.4
1976-77	95,275	8,111	8.5
1977-78	103,957	6,460	6.2
1978-79	142,177	1,680	1.2
Average	104,305	6,063	5.8

^a Florida Citrus Mutual, 1972 to 1979.

period; thus the estimated average loss amounts to about 14% of f.o.b. gross revenue on the average acre which would be affected by the loss of lead arsenate.¹³

Consumer Impacts.--For the period September 1 to November 15, Florida fresh grapefruit accounts for a major percentage of the commodity available to U.S. consumers. During recent growing seasons (1976-1979), Florida has accounted for approximately 85.4% of U.S. fresh grapefruit marketed during this period (Florida Citrus Mutual, 1976, 1977, 1978, and 1979). A reduction in supply of this magnitude would have an "adverse price effect" for consumers purchasing fresh grapefruit from Texas, California, and Arizona. Of particular importance is the fact that fresh grapefruit would not be available to a major segment of the consuming public during the September to November 15 period.

The negative impact that would be felt by consumers of fresh market grapefruit would be offset, in part, by the downward pressure on prices that would be expected in the remainder of the marketing season. With the assumption that total annual production would remain approximately unchanged after a lead arsenate cancellation, the greater quantities marketed in each week of the remainder of the season would be expected to result in a reduction in f.o.b. and producer level prices that would be passed on, in part, to consumers. The extent to which this price reduction would be passed on to consumers cannot be estimated with any precision, however. It is likely that only part of the reduction in price during the latter part of the season would be passed on to consumers in the form of lower prices at the retail level.

¹³ During the period covered by this analysis, there were approximately 93,400 acres of bearing seedless white and pink grapefruit in Florida (Florida Agric. Statistics, 1978). Average annual gross f.o.b. revenue = \$104,305,000 ÷ 93,400 acres = \$1,117 per acre. Average gross revenue loss is estimated at \$6,063,000 ÷ 37,600 affected acres = \$161 per acre. Average percentage gross revenue loss therefore approximates 14.4% per affected acre (\$161 ÷ \$1,117).

Table 63.--Summary of impacts on Florida grapefruit growers, average of 1971-72 through 1978-79 seasons

Item	With Lead Arsenate	Without Lead Arsenate	Economic Impact
- - - - - 1,000 Dollars - - - - -			
Treatment cost			
Materials ^a	310.5	--	310.5
Annual revenues			
Interior			
White	17,910	16,126	1,784
Pink	22,966	20,679	2,287
Indian River			
White	32,061	31,103	958
Pink	27,905	26,870	<u>1,035</u>
			6,064
Estimate of net loss			5,753.5

^a No labor or equipment costs are assigned because material is applied with pesticides that would still be needed without lead arsenate. Material cost: \$1.39 per pound of active ingredient times an average rate of 5.94 pounds per acre.

Several difficulties arise in trying to estimate the possible magnitude of impact at the consumer level. First, retail level data for fresh grapefruit are geographically incomplete and of questionable accuracy. Though limited data are available for certain cities in the Northeast (Baltimore, Boston, and New York), these data do not form an adequate base for the measurement of consumer impact for the entire U.S. retail market. Second, to the extent that retail price data are available for a few urban areas, less than two seasons' shipment data are available that show the geographic markets into which fresh Florida grapefruit are shipped. Thus, additional problems would arise in trying to estimate retail price impact on those few areas in which adequate data have been generated.

Limitations of the Analysis

Although the figures for lead arsenate usage and seasonal revenue impacts resulting from cancellation presented in this analysis are reported as point estimates, they represent approximations of lead arsenate use and economic impacts. The R^2 values for the four price-estimating equations developed herein indicate that the predictive capacities of the equations are somewhat limited and that the results obtained are subject to interpretation. It is the consensus opinion of the analysts, however, that, given the nature of the analysis and the data available, this report presents a reasonable estimate of the magnitude of the economic impacts likely to occur in the event lead arsenate use on grapefruit is canceled.

The difficulties involved in preparing the analysis are also reflected in the lack of quantified consumer effects. Too little is known of the effect of the potential cancellation upon specific production and marketing mechanisms to permit more than a qualitative assessment of expected consumer impacts. Additionally, data limitations concerning specific retail price responses and consumer demand patterns would limit the reliability of predicting such effects even if the fruit maturity, production, and shipment parameters could be assessed with a high degree of confidence.

Lead Arsenate—Cherry Fruit Fly

Current Use Analysis

Lead arsenate is registered to control a variety of cherry pests, the most significant of which are the cherry fruit fly and cherry leaf spot. Other pests for which lead arsenate is registered are pear slugs, snails, syneta beetles, rose chafer, plum curculio and brown rot (EPA, 1979). Lead arsenate is not currently listed in any of the State recommendations. Those pesticides currently registered and recommended are; for cherry fruit fly control: azinphosmethyl, parathion, malathion, carbaryl, and diazinon; for cherry leaf spot: benomyl, ferbam, folpet and captan.¹⁴

Lead arsenate is not currently used for cherry pest control and alternatives are relied upon exclusively as previously discussed. Although the quantity of these chemicals applied depends upon the presence and severity of the pests in the orchard, spray schedules recommend approximately five applications of fungicides per season to control leaf spot.¹⁴ Approximately five applications of insecticides per season are used in Oregon to control fruit flies (Zwick, 1979).

Data for the quantity of these chemicals applied nationally were not available. However, Table 64 illustrates approximate quantities applied on a per-acre basis.¹⁴

Performance Evaluation of Lead Arsenate and Alternatives

Pest Infestation and Damage.--Cherry fruit flies are economically important pests. Adult females feed on exudates by puncturing leaves and fruit with the ovipositor. Egg laying takes place approximately 5 to 6 days after mating, and an average of 386 eggs may be laid by one fly. Eggs are inserted into the fruit through small slits made by the ovipositor. Larvae hatch approximately 1 week later and begin feeding on the fruit.

Infested cherries become misshapen and undersized, often with one side of the fruit decaying. Broken burrows extend through the fruit (Metcalf and Flint, 1962).

Due to quarantine laws and marketing cooperatives standards, cherries have a zero tolerance to fruit fly infestations (Howitt, 1979; and Facteau, 1979). Detection of this pest in a shipment of cherries results in condemnation of the entire stock.

Cherry leaf spot is an important fungal disease that causes premature leaf drop that can seriously weaken trees.

¹⁴Indiana, 1975; Montana, 1975; New Jersey, 1976; Ohio, 1977a; Pennsylvania, 1977a; Tennessee, 1977; Virginia, 1978b; and Washington, 1977.

Table 64.--Annual use per acre of lead arsenate and alternatives on cherries^a

Pesticide	Pounds a.i./ 300 Gallons ^b	Number of Applications	Total Pounds a.i./Acre
Lead arsenate	6.0	5	30.0
Fungicides:			
Benomyl	1.5	5	7.5
Folpet	4.5	5	22.5
Ferbam	4.5	5	22.5
Captan	6.0	5	30.0
Insecticides: ^c			
Azinphosmethyl	1.0	4-6	5.0
Parathion	1.0	4-6	5.0
Malathion	4.0	4-6	20.0
Diazinon	2.0	4-6	10.0
Carbaryl	4.0	4-6	20.0

^a Source: State recommendations.

^b Approximately 300 gallons spray mixture are required to treat 1 acre of cherry trees (Pennsylvania, 1977).

^c Insecticide applications are maximum annual usages representative for Oregon. Carbaryl is not considered in the Oregon Spray Schedule (Zwick, 1979).

The fungus overwinters on fallen leaves and fruit; the following spring spores are borne by the wind to attack leaves on the trees. Keeping the area around the trees clean of litter can help, but this is only a halfway measure and is not sufficient to control the fungus adequately (Kilpatrick, 1979).

Comparative Performance Evaluation.--The alternative pesticides available are adequate pest controls; lead arsenate is currently not used or available. Table 65 illustrates lead arsenate production levels from 1950 through 1973.

Comparative Costs.--Table 66 illustrates the cost differences between lead arsenate and alternatives on a seasonal per-acre basis. Fungicide alternatives are generally less expensive; seasonal per acre treatment cost differences range from 22.72 to \$19.80. All insecticide alternatives are less expensive; seasonal per-acre treatment cost differences range from 37.10 to \$6.50.

Use Impacts

User Impacts.--No immediate impact is expected from the cancellation of lead arsenate. If pests developed resistance to organic chemicals without changes in the marketing standards for the cherry fruit fly maggot, the long-run impacts upon Oregon and Washington producers would be significant.

Existing California as well as Oregon and Washington marketing cooperatives standards will not tolerate the cherry fruit fly maggot; therefore detection of this pest in any fruit shipment will result in condemnation. The entire output of about

Table 65.--United States lead arsenate production, 1950-1973^a

Year	1,000 Pounds	Year	1,000 Pounds
1950	39,434	1962	9,930
1951	25,416	1963	7,842
1952	14,286	1964	9,258
1953	14,196	1965	7,098
1954	15,620	1966	7,328
1955	14,776	1967	5,952
1956	11,756	1968	9,016
1957	11,920	1969	9,204
1958	14,938	1970	4,156
1959	12,904	1971	6,168
1960	10,062	1972	5,164
1961	10,446	1973	3,946
		1974-80 ^b	

^a Source: Hertzmark, 1974.

^b Data not available under current regulations.

Table 66.--Seasonal per acre application costs for lead arsenate and alternatives on cherries^a

Pesticide	Pesticide Cost/Pound a.i.	Pound a.i. Applied/ Season	Total Pesticide Cost/Season	Cost Difference/ Season
	<u>Dollars</u>	<u>Pounds</u>	<u>Dollars</u>	<u>Dollars</u>
Lead arsenate	1.59	30.0	47.70	--
Fungicides:				
Benomyl	9.00	7.5	67.50	19.80
Folpet	1.78	22.5	40.05	-7.65
Ferbam	1.11	22.5	24.98	-22.72
Captan	1.20	30.0	36.00	-11.70
Insecticides:				
Azinphosmethyl	4.30	5.0	21.50	-26.20
Parathion	2.60	5.0	13.00	-34.70
Malathion	.85	20.0	17.00	-30.70
Diazinon	1.06	10.0	10.60	-37.10
Carbaryl	2.06	20.0	41.20	-6.50

^a Source: Prices from EPA price lists for 1978, and from personal communications with Chevron Chemical Co., Chemagro Chemical Co., and Ciba-Geigy Corp.

154,000 tons of cherries produced on 20,000 and 24,000 acres in Oregon and Washington are potentially subject to impact if widespread resistance to organic pesticides occurs (Facteau, 1979a).

The effects of cherry leaf spot infestations would take longer to be realized. Trees would weaken considerably and lose their vitality over time.

By preliminary 1977 farm level prices of \$428 and \$538 per ton of sweet variety cherries produced in Oregon and Washington (USDA, 1978), the value of output that is conjecturally subject to future impact exceeds \$75 million.

Market Impacts.--No immediate market impacts will occur because lead arsenate is not currently used by cherry producers.

Oregon and Washington, however, accounted for over 57% of the total 1977 U.S. production of sweet variety cherries (USDA, 1978). If future cherry fruit fly resistance to organic insecticides develops in this region without changes in current marketing standards, supply shortfalls and market price increases could be substantial.

Consumer Impacts.--No immediate consumer impacts are expected.

If the cherry fruit fly developed widespread resistance to organic pesticides with no changes in the existing marketing standards, future supply shortfalls would cause consumer price increases. Estimates of either the magnitude or time occurrence of such impacts would be highly conjectural.

Social and Community Impacts.--No immediate social and community impacts are expected. Future social and community impacts are possible if the cherry fruit fly develops widespread resistance to organic insecticides with no changes in marketing standards. However, the potential for such impacts is quite speculative.

Macroeconomic Impacts.--No impacts are expected.

Limitations of the Analysis

Long-term impacts can only be speculated; impacts will not occur unless target pests develop widespread resistance to alternative controls.

Summary of Economic Impact Analysis of Canceling Lead Arsenate

Lead Arsenate—Growth Regulators

- | | |
|--------------------|--|
| A. USE: | Lead arsenate use as a growth regulator on Florida grapefruit. |
| B. MAJOR FUNCTION: | Reduces acidity in early-season varieties, thereby enables maturity standards to be met earlier. Lengthens marketing season by 2.5 months (mid-November-June to September-June). |

C. ALTERNATIVES:

Major registered chemicals:

None.

Nonregistered chemicals:

Calcium arsenate is effective but not registered.

State recommendations:

Florida application rate: 4 to 12.5 pints lead arsenate 4 pounds flowable per 500 gallons spray, depending on variety.

Nonchemical regulators:

None.

D. EXTENT OF USE:

Active ingredient applied and acres treated:

224,000 pounds a.i. on about 37,600 acres (35% of Florida grapefruit) annually.

E. ECONOMIC IMPACTS:

User:

Annual gross revenue reductions range from 1.68 to \$9.27 million (average \$6.06 million). Average gross revenue loss = \$161 per affected acre or 14% of per-acre revenue. After deducting cost of lead arsenate, average revenue loss approximates \$5.75 million annually or \$153 per affected acre.

Market, consumer:

Florida provides 85% of early-season fresh grapefruit (Sept.-mid-Nov.). Supply reductions of this magnitude would increase retail prices sharply in early season. Increased marketings in later season (Nov.-June) would reduce prices in this period. Net consumer impact undetermined.

F. LIMITATIONS OF THE ANALYSIS:

- 1) Lead arsenate usage levels based on 1977 data.
- 2) Statistical limitations of price-estimating equations indicate results subject to interpretation.
- 3) Data limitations prevent quantitative analysis of market and consumer impacts.

G. PRINCIPAL ANALYSTS:

John Bratland
Natural Resource Economics Division
ESCS
USDA
Washington, D.C.

Gary Fairchild
Fla. Dept. of Citrus
Univ. Fla.
Gainesville, Fla.

Linda DeLuise and Mark Luttner
Economic Analysis Branch
OPP
EPA
Washington, D.C.
Feb. 1980

Lead Arsenate—Cherry Fruit Fly

- A. USE: Lead arsenate use on cherries
- B. MAJOR PESTS CONTROLLED: Cherry fruit fly, cherry leaf spot
- C. ALTERNATIVES:
- Major Registered Chemicals: Cherry leaf spot: benomyl, captan, ferbam, folpet
- Cherry fruit fly: azinphosmethyl, parathion, malathion, diazinon, carbaryl
- State Recommendation: Same as above
- Non-chemical Control: Cherry fruit fly: none
- Cherry leaf spot: keeping grounds surrounding trees clean.
- Efficacy of Alternatives: All provide adequate control; however, development of pest resistance is possible.
- Comparative Costs: Per-acre costs of alternatives range from 10.60 to \$41.20 for an insecticide, and 24.98 to \$67.50 for a fungicide. Per-acre cost of lead arsenate is \$47.70.
- D. EXTENT OF USE: No lead arsenate being used at present. Alternatives are currently effective.
- E. ECONOMIC IMPACTS: No immediate impacts; future impacts may be experienced if pest resistance develops.
- F. SOCIAL/COMMUNITY IMPACTS: None
- G. LIMITATIONS OF THE ANALYSIS: Longer term impacts can only be speculated. No impacts will result unless pest resistance to alternatives develops.
- H. PRINCIPAL ANALYST AND DATE: Elena Boisvert
Economic Analysis Branch, OPP
U.S. Environ. Prot. Agency
Sept. 1979

Sodium Arsenate

Sodium Arsenate—Ant Control

Sodium arsenate is a white powder of moderate solubility in water. It is formulated in various baits for control of ants and frequently contains combinations of water, glycerin, sugar, and honey. Some baits, especially designed for protein- or grease-loving ants, contain beef liver, peanut butter, or a soybean product. The amount of sodium arsenate in bait formulations ranges from 0.3 to 3.0%. The consistency of baits varies from a syrup to a paste. Syrups are frequently impregnated on an absorbent, inert base.

The EPA files show 12 products registered as containing sodium arsenate, but it is not known if all of these are registered for ant control (Table 67).

Methods of Application

All formulations for ant control are baits, and application is therefore limited to ready-to-use formulations. Frequently, the bait ingredients are in small, tamper-proof containers that are punctured to permit the entry of ants. These self-contained devices are placed in protected or secluded places near the trails and other sites of ant activity. Label directions call for placement in wall voids, behind cabinets and fixtures, in enclosed crawl spaces, and other protected locations not accessible to children, pets, or wildlife, nor where contamination of food can occur. The latter is highly unlikely with self-contained devices. Some formulations are liquids, however, which are poured from the container in small quantities onto wax paper or cotton, and placed in the same locality as described above.

Sodium arsenate is generally applied by the householder rather than by commercial applicators. There are two reasons for this situation. One is that commercial applicators prefer to spray thoroughly for ants to provide immediate relief for the customer. The other is that the purchase and use of baits by the householder is a convenient and inexpensive method, especially for small infestations.

Use Patterns and Efficacy

Baits are used for ant control only when needed, and thus there is no set pattern of use. Placement is made manually, and large numbers are not used. Two factors favor infrequent application: 1) Sodium arsenate is long-lasting even in the small quantities used; 2) the toxic action is relatively slow, so that ants carry the bait back to their nests, and transfer the toxicant to developing larvae. The latter behavioral pattern frequently results in the elimination of a colony with a minimum use of the insecticide.

Sodium arsenate is an effective toxicant against most species of common ants. Satisfactory control can be expected when small populations are present or when there are alternative sources of food outside the area of annoyance. Large ant colonies may present a greater problem requiring a greater distribution of bait stations.

Exposure Analysis

Once baits have been formulated and packaged, exposure can occur only if packages are opened. Even then, baits that are marketed in small enclosed containers are relatively inaccessible to children and pets. Bait formulations that have to be poured onto a suitable substrate are more hazardous and must be placed with special

Table 67.--Companies with labels registered for sodium arsenate use
in ant control^a

EPA Registration Number	Company	Active Ingredient
		<u>Percent</u>
29-4	Jones Product Co.	1.5
30-1	W. R. Sweeney	2.3
55-1	Fatsco	3.0
149-4	Senoret Chemical Co.	2.27
149-2	Senoret Chemical Co.	0.92
419-4	Cenol Company	2.37
498-1	Chase Products Co.	0.95
2341-3	Clark Nowlin Co.	3.08
2443-1	Atlanta Chemical Co.	1.88
4972-8	Protexall Chemical	2.27
7992-5	TNT Chemical Inc.	1.66
38542-10224	Richard Ludwig	2.0

^a Source: Survey of Manufacturers, 1979.

care; however, the amount dispersed in a single location and the total amount used at any one time are quite small. Further, antidotes are relatively available, consisting of either mustard or salt in water. Although accidental poisonings are annually recorded for arsenicals, those resulting from the use of sodium arsenate are infrequent and could be eliminated with strict adherence to the label. Baits packaged in container stations are preferred.

Fate in the Environment (See Volume I, Chapter 4)

Alternatives

Even though sodium arsenate has been in use for about a century, use has been lower since the advent of chlorinated hydrocarbons and other synthetic organic insecticides. In structural ant control, dieldrin and chlordane have been extensively used, principally as sprays. Neither is now registered for ant control. Among bait materials, Kepone has been most widely used in structures, and its close relative, Mirex, outdoors. Neither is now available. The lack of alternatives in situations where baits are desired in structures implies a growing reliance on sodium arsenate.

There are, however, a number of materials used principally as sprays that are still registered. These include chlorpyrifos, diazinon, and propoxur. Propoxur is formulated also as a bait, but performance is not satisfactory because it is too fast-acting to be carried back to the nest.

Summary of Biological Analysis—Sodium Arsenate for Ant Control

Sodium arsenate, long used as the toxic ingredient in bait formulations for ant control, is still registered by a number of firms. The principal use is by the householder who relies on baits to achieve control of modest ant infestations. The advantages of sodium arsenate baits are: Ease of use, limited quantities used, the transport of the toxicant to the colony, and the continuance of control. Formulations packaged in small ready-to-use containers are the safest of such products. In light of the recent loss (no longer registered) of insecticides which have been commonly used for ant control, including bait products, the continued use of sodium arsenate for sweet-eating ant control seems well justified. Low exposure potential from the small amounts of toxicant used per location favors the continued use of sodium arsenate for the control of sweet-eating ants.

Economic Impact Analysis of Canceling Sodium Arsenate

Sodium Arsenate—Ant Control

Current Use Analysis

Ants present a nuisance or annoyance problem. Sodium arsenate is generally applied in bait form by the householder. Commercial applicators use other insecticides to spray thoroughly for ants, providing immediate relief for the customer. The use of baits by the householder is a convenient and inexpensive method of control, especially for small infestations.

According to one manufacturer, householders using sodium arsenate usually purchase a 1- or 2-ounce bottle of sodium arsenate about once during a 5-year period (Roberts, 1980). Infrequent application provides sufficient control, as sodium arsenate is long lasting and its slow toxic action allows the ants to carry the bait back to the nest and transfer the toxicant to the developing larvae.

Alternatives

There are two registered alternatives to sodium arsenate for indoor residential use as baits--Kepone and propoxur. Kepone is no longer available. Propoxur is a faster-acting insecticide than sodium arsenate, allowing a much smaller proportion for the adult ants to carry the bait back to the nest. Thus, sodium arsenate is considered the more effective of the 2 pesticides for indoor residential ant control.

A number of materials are used principally as sprays, including chlorpyrifos, diazinon, and propoxur. Application of these materials as sprays is restricted to custom applicators. It generally takes 2 applications to remove the entire ant population, as not all of the nests are found during the first application.

Use Impacts

In 1979, approximately 700,000 householders purchased containers of sodium arsenate (Survey of Manufacturers, 1979). Each of these containers generally provides

sufficient quantities of material to control household ant infestations over a period of several years.

As sodium arsenate and propoxur baits are approximately equal in cost, the switch to a propoxur bait would have minimal impact on the householder in terms of application costs. Because propoxur is a less effective bait than sodium arsenate, however, the householder may be faced with the choice of the continued nuisance of the presence of an ant population, or employing an extermination service. If an extermination service is employed, removing the entire ant population generally requires two spray applications, with an approximate cost of \$30 per application. The \$60 total exterminator service cost is to be compared with an approximate cost of \$2.60 using sodium arsenate bait applied by the householder.

For modest infestations, the propoxur bait may provide satisfactory control for many householders. Data are not available on the number of householders that would use the services of commercial exterminators if propoxur baits did not provide satisfactory control. For an estimated 700,000 householders, the cost would range from no additional cost using propoxur baits (assuming all obtained satisfactory control) to about \$42 million additional cost if all used the services of commercial exterminators (assuming a \$60 cost per household).

Summary of Economic Impact Analysis of Cancelling Sodium Arsenate for Ant Control

- A. USE: The principal use is in baits for indoor residential ant control.
- B. INSECTS CONTROLLED: Ants.
- C. ALTERNATIVES:
- Chemical alternatives: Chlorpyrifos, diazinon, and propoxur are applied principally as sprays by commercial applicators for indoor residential ant control. Only propoxur and Kepone are registered for use as baits. Kepone is no longer available.
- Comparative efficacy: The alternative spray applications provide satisfactory control. Propoxur baits are less efficacious than sodium arsenate baits for complete removal of an ant infestation.
- Comments: The advantages of sodium arsenate baits are:
1) the transport of the toxicant to the nest for complete removal of an infestation, 2) low cost, 3) the continuance of control, and 4) ease of use.
- D. EXTENT OF USE: Sodium arsenate is generally applied by householders who prefer the convenience and low cost of baits, especially for small or modest infestation. In 1979, approximately 700,000 householders purchased containers of sodium arsenate.

E. ECONOMIC IMPACT:

For those householders purchasing propoxur baits, there would be minimal economic impact, as the cost of propoxur and sodium arsenate baits is approximately the same. For each householder using commercial exterminating services, there would be an approximate cost of \$60 for the two applications generally needed for complete removal of an infestation. This cost is to be compared with approximately \$2.60 using either a sodium arsenate or propoxur bait. If all of an estimated 700,000 householders used commercial exterminator services, they would incur an additional total cost of approximately \$42 million, assuming an average cost of \$60 per household.

Market:

Some increased demand for commercial exterminating services could result without availability of sodium arsenate baits.

Consumer:

Minimal impact.

Macroeconomics:

Not known.

F. SOCIAL/COMMUNITY IMPACTS:

Not known.

G. LIMITATIONS OF THE ANALYSIS:

Estimates are not available for the number of householders that would use commercial exterminating services if propoxur did not provide satisfactory control for some infestations.

H. ANALYST AND DATE:

Walter Ferguson
ESCS
USDA
Washington, D.C.
Feb. 1, 1980

Sodium Arsenite

Sodium Arsenite—Non-Selective Herbicide (Soil Semi-sterilization and Tree Killer)

The high water solubility of sodium arsenite (Table 5) facilitates its use; it is commonly formulated as a concentrated aqueous solution. A total of 70 registrations are on file (Table 68) for products containing 15 to 66% (wt/wt/ NaAsO_2). The most common formulations are 40% and 42.5% NaAsO_2 . Many of the manufacturers and distributors listed in Table 68 consider sodium arsenite as only a small part of their total business, and several indicated they are depleting existing stocks and will evaluate continued handling of the product after EPA has issued new regulations. The OSHA air standards have also resulted in curtailment of manufacture and formulation of sodium arsenite.

Sodium arsenite is registered for a number of pest control problems including non-selective herbicide/defoliant, soil semi-sterilization in industrial areas,

Table 68.--Companies with labels registered for sodium arsenite agricultural uses^a

EPA Registration Number	Manufacturer	Percent (wt/wt) NaAsO ₂	As ₂ O ₃
		<u>Percent</u>	<u>Pound/ Gallon</u>
4-109	Bonide	42.5	4
5-31	Empire Lab.	48.75	4.5
106-1	Brulin	45.5	4
192-90	Drexol Ind.	43.4	4
239-61	Chevron Chem.	42	4
239-289	Chevron Chem.	55	6
359-1	Rhodia, Inc.	42.5	4
359-228	Rhodia, Inc.	57.4	6
363-1	Coopers Creek Chem. Corp.	42.5	4
402-53	Hill Mfg.	40	4
421-368	James Varley & Sons	42.4	4
421-398	James Varley & Sons	59.5	6
446-1	James Good	40	3.7
491-3	Selig Chem. Ind.	44	4
551-1	Baird & McGuire	16.5	2
551-88	Baird & McGuire	33.0	3
551-208	Baird & McGuire	66	8
551-214	Baird & McGuire	46.9	4
604-17	Hammond Paint & Chem.	30	2.6
769-287	Woolfolk Chem. Works	40	4
779-2	Fasey & Besthoff	42.5	4
839-59	Bell Chem. Co	40	4
842-113	G. S. Robins Co.	55	6
962-349	L. A. Chemical	52.5	6
962-10173 ^b	L. A. Chemical	43.4	4
CA962-50067 ^b	L. A. Chemical	43.4	4
1022-109	Chapman Chemical	40	4
1057-20	Dolge	42.5	4
1266-43	Malter International	40	4
1269-22	DeWitt Chem.	50	5.5
1270-42	Zep Mfg.	50	5.5
1325-60	Davis Weil Mfg.	40	4
1386-136	United Corp.	42.5	4
1421-74	Dettelbach Chem. Corp.	40	4
1439-234	Blue Spruce	66	8
1624-55	U.S. Borax & Chem.	17	2
1685-26	State Chem. Mfg.	45.4	4
1691-16	Chem. Compounding Corp.	35	3
1691-16	Chem. Compounding Corp.	53.86	6
1769-37	National Chemsearch	40	4
1969-70	National Chemsearch	40	4
1769-121	National Chemsearch	40	4
1926-30	Navy Brand Mfg.	55.8	6
2155-26	Schneidi, Inc.	44	4
2169-27	Patterson Chem.	40	4
2270-684	Huge Co., Inc.	40	4

Table 68.--Companies with labels registered for sodium arsenite agricultural uses^a --continued

EPA Registration Number	Manufacturer	Percent (wt/wt) NaAsO ₂	As ₂ O ₃
		Percent	Pound/ Gallon
2831-4	Napasco Chem. Co.	40	4
3040-38	Edco Chem. Co.	15	2
3040-39	Edco Chem. Co.	40	4
3862-43	ABC Compounding Co.	40	4
4450-6	Chemex Industries	25	3
4581-102	Pennwalt	66.1	8
4581-205	Pennwalt	45.9	4.5
4581-229	Pennwalt	53.86	6
4931-33	Good-Life Chemicals	42.5	4
5664-1	Technical Maintenance Products	38	3.5
6294-22	Comet Mfg.	40	3.7
6720-150	Southern Mill Creek Products	42.5	4
6720-181	Southern Mill Creek Products	41.7	3.5
6762-29	Stern Chem. Corp.	20	2
6837-22	Wilmar	20	2
6837-30	Wilmar	40	3.7
7273-61	Crown Chemicals	40	4
7273-61	Crown Chemicals	55.8	6
8047-9	Poly-Chem. Inc.	40	3.7
9791-4	Yukon Service Co.	53.86	4
10204-11	Marko Chemical	30	2.6
10827-4073	Industrial Solvents	40	3.7
13437-4074	Du-Cor Chemical Corp.	40	3.7
22058-2	Sharp Chemical	40	3.7

^a Some are no longer manufacturing or selling the product; no attempt was made to ascertain these (Survey of Manufacturers, 1979).

^b 962-10173 and CA962-50067 are special local need labels for California only.

rights-of-ways and beneath paving, subterranean termite control, and control of certain fungus-related diseases of grapes in California vineyards. It is not available for home use; only licensed commercial applicators may purchase the product. With the exception of control of Black Measles in grapes, numerous alternatives are currently available. The amount of sodium arsenite used nationally has undoubtedly declined markedly in recent years. However, no production or use figures are available. California estimates that about 60,000 to 75,000 gallons of 43.4% solution were used in 1978-79, or about 430,000 pounds of NaAsO₂ (Elliott, 1979; Stephens, 1979). A marked increase in price of the material has occurred recently, especially in California, due to lack of availability. Crude As prices have quadrupled since 1975, and sodium arsenite now retails for about \$1.75 per pound of As.

Methods of Application

The concentrated solution is usually diluted before use as a semi-sterilant. Label recommendations vary widely (Table 69). The final As concentration ranges from 0.03 to 0.8 pound As/gallon (about 3,600 to 94,000 mg As/liter). The labels often do not readily distinguish between use as a contact herbicide and as a semi-sterilant. Those recommending low application rates (17 to 50 pounds As/acre) are more likely used as a contact herbicide. Soil semi-sterilization rates recommended range to a high of 2,900 pounds per acre. The highest recommendations are on the Los Angeles Chemical Corp. label (EPA 962-349) for the control of perennial weeds and grass on medium-textured soils.

Various application methods are used. Sprayer or sprinkling-can application is often recommended, with more dilute solutions usually being applied by sprinkler.

For tree control, either the undiluted or a slightly diluted product is recommended. Application involves direct pouring of the solution on gashes or cavities in the tree or over the entire stump.

Use Patterns and Efficacy

No use pattern data are presently available, especially for soil semi-sterilization in industrial areas and tree control. Apparently, sodium arsenite has not been widely used for several years in the paving industry or for railroad right-of-ways (Chappell, 1979).

Exposure Analysis

The semi-sterilization and tree control uses are of the small multi-user variety and exposure analysis is difficult if not impossible to determine. Applicator contact would seem a distinct possibility in any of the above uses. Non-target organisms, especially desirable vegetation, may well be affected if application is done poorly, and this fact is clearly pointed out in several of the labels.

If the application site is clearly restricted, little exposure to wildlife or humans should ensue from sodium arsenite use; however, changing land-use patterns could lead to unexpected exposure for many years (e.g., if an industrial area was converted to a residential area). Sodium arsenite should never be applied in areas with public access, or areas frequented by wildlife. It would appear, however, that present labels do not entirely restrict this possibility, inasmuch as airports, warehouses, building foundations, fence rows, drive-in theaters, sand traps in golf courses, and cemeteries are recognized use areas (Livingston, 1978; Vento, 1978; Haney, 1978; Heneke, 1978; Alden, 1978; EPA, 1972; and EPA, 1977).

Fate in the Environment

Arsenite is rapidly oxidized to arsenate in aerobic environments, and thus its chemistry becomes the chemistry of the arsenate ion (Volume I, Chapter 4). In anaerobic environments, it may be reduced to volatile alkyl arsines. At high application rates, significant leaching and runoff might occur in unpaved areas.

Alternatives

Owing to its phytotoxicity and stability, sodium arsenite is a highly effective, long-lasting, and relatively inexpensive non-selective herbicide and soil semi-sterilant.

Table 69.--Summary of selected label recommendations for use of sodium arsenite for wood and tree stump control

Weed Control (Soil Semi-sterilization)						
EPA Registration Number		Dilution (Gallon/ Gallon)	Pound As/Gallon Undiluted Product	Application		Tree Stump Control
				Method	Rate, Pounds As/Acre	
10204-11	Bare ground	1:6	0.3	--	130-220	Pour undiluted into cavities, over stumps.
446-1	Bare ground	1:49	0.06	Sprinkling can	120	--
	Bare ground	1:15-1:30	0.09-0.18	Spray or sprinkle	--	Pour 1:3 dilution on stumps.
1769-70	Bare ground	1:50-1:100	0.03-0.06	Sprayer	35	Pour undiluted in gashes or on stumps.
	Paving	1:2	0.9	--	610	
22058-2	Bare ground	1:36	0.08	--	30	None.
	Paving	1:4.5	0.5	--	250	None.
769-287	Bare ground	1:5-1:10	0.2-0.5	--	17	Pour 1:3 dilution on stumps.
	Paving	1:10	0.2	--	610	
779-2	Bare ground	1:3-1:40	0.08-0.8	Spray or sprinkle	130-260	Pour 1:1 dilution on stumps.
1057-20	Bare ground	1:40	0.08	--	38	None.
4931-33	Bare ground	1:5-1:10	0.25-0.5	Spray	20	None.
	Paving	1:5-1:10	0.25-0.5	Spray or sprinkle	>20	None.
359-1	Bare ground	1:20	0.15	Spray	54	None.
962-349	Paving	none	4.5	--	488-2,900	None.
359-228	Bare ground	1:18	0.24	Spray	38	None.
1926-30	Bare ground	1:5-1:20	0.2-0.8	Spray or sprinkle	38	Pour 1:3 dilution on stumps or gashes.
1439-235	Bare ground	1:9	0.6	Spray or sprinkle	38	Pour 1:10 dilution on stumps or gashes.

Alternatives for weed control in non-crop areas were obtained from the compilation by EPA (1977a) and from Thomson (1977a). Non-arsenical alternatives are listed in Table 70 and a summary of state-recommended mixtures in Table 71. Many alternative chemicals exist for most uses. For weed control under paving, however, only

Table 70.--Alternative non-arsenical herbicides for use on non-crop areas^a

Compound	Weed Control		Tree/Stump Control	Comments
	Selectivity ^b	Duration ^c		
Amitrole	2	y	Yes	RPAR-perennials
AMS	2	y	Yes	Woody plant perennials
Atrazine	1,2	y,L	No	
Borax	1,2	L	No	Perennials, paving
Bromacil	1,2	L	No	
Carbon bisulfide	1	s	No	Uncommon use
2,4-D ^d	4	s-y	Yes	Some perennials
Dalapon	3	s	No	Some perennials
Dicamba	1,4	L	Yes	Some perennials
Dichlobenil	1	L	No	Incorporated
Dinoseb (DBNP)	(1)	s	No	Repeated application
Fenac	1,4	L	No	Perennials
Fenuron TCA	--	y	Yes	
Glyphosate	2	s	No	Perennials
Karbutilate	1,2	--	Yes	Perennials
Krenite	4	s	Yes	Tree buds
Linuron	1,2(3)(4)	y	No	Annuals
MCPA	4	s-y	No	Some perennials
Methyl bromide	1	s	No	Semi-sterilant
Monuron	1	y-L	No	RPAR
Paraquat	2	s	No	RPAR-top kill
Petroleum oils	1,2	s-y	No	Top kill
Picloram	4	y-L	Yes	Some perennials
Prometon	1,2	L	No	Perennials
Simazine	1,2	y,L	No	Root uptake
Silvex	4	y	Yes	RPAR ^d
Sodium chlorate	1,2	L	No	Fire hazard without borate
Sodium TCA	3	y	No	Paving
2,4,5-T	4	s-y	Yes	RPAR, woody ^e
2,3,6-TBA	1,2	y-L	Yes	RPAR, woody
Tebuthiuron	1,2	L	Yes	Woody
Gas-flaming	--	s	No	

^a Source: EPA, 1977a; and Thomson, 1977a.

^b 1 = nonselective preemergence; 2 = nonselective postemergence; 3 = grasses; 4 = broad-leaf weeds.

^c s = 2-4 wks; y = <1 yr; L = >1 yr.

^d 2,4-D may be RPAR'd.

^e Suspended 3/1/79.

Table 71.--Some common herbicide mixtures for non-crop area^a

Mixture	Selectivity ^b	Duration ^c	Uses ^d
Amitrol ^e + bromacil + fenac	1,2,4	y	FR,I,G
Amitrol ^e + simazine	1,2	y	I,G
Atrazine + amitrol ^e + fenac	1,2	y-L	G
Atrazine + borate + chlorate	1,2	L	G
Atrazine + fenac	1,2,4	y	G
Atrazine + prometone	1,2	L	G
Borate + bromacil	1,2	L	FR,ROW,G
Borate + monuron ^e	1,2	L	FR,ROW,G
Bromacil + diuron	1,2	y-L	G
Bromacil + fenac	1,2,4	L	G
Chlorate + borate	1,2	L	FR,ROW,PG
Chlorate + borate + monuron ^e	1,2	L	FR,ROW,G
Chlorate + borate + bromacil	1,2	L	FR,ROW,G
Chlorate + borate + prometone	1,2	L	FR,ROW,G
Chlorate + borate + prometone + simazine	1,2	L	G
2,4-D + dalapon	2	s-y	FR,G
2,4-D + dicamba	1,4	y	ROW,G
2,4-D + petroleum oils	1,2,4	y	T/S
2,4-D + picloram	4	y-L	FR,T/S
2,4-D + 2,4,5-T ^f	1,2,4	y	T/S
Dalapon + silvex ^f	3,4	s-y	FR,ROW
Dalapon + 2,4,5-T	3,4	s-y	FR,ROW
Dalapon + TCA	3	s-y	G
Dicamba + picloram	1,4	y-L	T/S
Dicamba + 2,4,5-T ^f	1,4	s-y	T/S
Diuron + TCA	1,3	y-L	FR,T/S
Petroleum oil + 2,4,5-T ^f	1,2	s-y	T/S
Picloram + 2,4,5-T ^f	4	y-L	T/S

^a Source: EPA, 1977a.^b 1 = nonselective preemergence; 2 = nonselective postemergence; 3 = grasses; 4 = broad-leaved.^c s = 2-4 wks; y = < 1 yr; L = > 1 yr.^d FR = fence row; ROW = right-of-way; P = under paving; G = general noncrop use; T/S = trees and stumps.^e RPAR'd or RPAR candidates.^f Suspended, 3/1/79.

sodium trichloroacetate (TCA) and borate-chlorate mixtures are recommended. TCA is effective for 60 to 90 days (Thomson, 1977a). Sodium borate-chlorate mixtures are highly effective for several years and have low toxicity (Thomson, 1977a).

Sodium Arsenite—Subterranean Termite Control

Only two available labels listed sodium arsenite for subterranean termite control. Based on Forest Service studies, the effect of 10% sodium arsenite applied for termite control is questionable in both test methods used for making the evaluation. It has proved effective in some cases of practical use under buildings. The National Pest Control Association. (Rambo, 1979) would like to retain use as a spot treatment on difficult control problems.

Methods of Application

The only available recommendation is for use in industrial or commercial termite control (EPA Registration No. 962-349). It reads,

"Apply in trench, 30 inches deep, but not below the top of footing, if this is shallower. Trench must extend all the way around the building being treated. Use 1 gallon of the diluted mixture (dilution not specified) per linear foot of trench including backfill soil. Use 2 gallons per 5 linear feet for trenches 15 inches deep. Also soak under and around porches and under each of the piers of the building."

The diluted solution normally contains about 10% sodium arsenite.

A California label (962-50067) recommends applying a 1:4 dilution of 43.5% sodium arsenite at 1 gallon per 40 ft² under slab or attached porches or at 1 gallon per 30 ft² of fill. On conventional buildings, apply 1 gallon to 10 linear feet alongside interior or exterior foundations, etc.

Hill-Smith Termite Control Co., Inc. (Smith, 1978) uses sodium arsenite only for special purposes. They specify dilution in an outdoor tank or a tank truck and application with proper equipment. The applicator uses rubber gloves, goggles, and protective clothing, and application methods minimize exposure (e.g., start at the point farthest from the exit and work back from there). Application is limited to slab and void injection; occasionally crawl spaces are treated. Applicator exposure is only during mixing and handling, and would be a maximum of 2 hours per day. They estimate a maximum of 60 workers hours of use per year.

Use Patterns and Efficacy

Smith (1979) states that the Forest Service publications no longer recommend sodium arsenite as a soil treatment for subterranean termite control because alternative chemicals are more effective. There are, however, no substitutes for control in industrial or commercial situations where the odors of organic solvents or insecticides could be a problem. Treatment should be limited further to those industrial situations in locations where the water table is not high, because of the high water solubility of sodium arsenite. Further, the opportunity for alkyl-arsine formation exists in wet locations (See Volume I, Chapter 4).

Exposure Analysis

No information is available. The potential for applicator exposure exists and damage to shrubs and trees is a distinct possibility if sodium arsenite is not applied properly. Residential use is not recommended primarily because of phytotoxicity to foundation plantings and lack of efficacy. The potential for alkyl-arsine formation also must be considered (See Volume I, Chapter 4).

Fate in the Environment (See Volume 1, Chapter 4)

Alternatives

Formulations of four materials--aldrin, dieldrin, chlordane, and heptachlor--are currently registered for use in treating soils to control native subterranean termites. These chemicals, when applied according to the prescribed rates and methods, have provided complete protection for 17 to 21 years in Gulfport, Mississippi tests (Johnston, et al., 1972).

Sodium Arsenite—Grape Disease Control

California ranks first nationally in grape production, and in 1974 grapes provided 6.0% of the total value of California agriculture (CCLRS, 1975). Garoyan, et al. (1975) and Moulton (1979) provide comprehensive production and economic reviews of the grape industry to date. They point out the dynamic nature of grape production and acreage over the post-war years. Acreage increased until recently with a shift to wine varieties over table and raisin varieties. Currently, raisin varieties are on the increase, but total acreage is stable. Table and raisin grape varieties can also be used for wine, but wine varieties have no alternative use. Thus, the industry is less flexible than formerly. Three years are required before a vineyard bears a marketable product, which makes adjustment of acreage to market conditions difficult and often leads to overproduction depending on weather (Moulton, 1979). There are two diseases, Black Measles and Dead-Arm, which can be controlled with sodium arsenite. Sodium arsenite treatment is used only when Black Measles is also present. Alternate materials are used otherwise.

Black Measles, also known as "Spanish measles" or "Apoplexy," was first described in France, where it is known as Esca (Moller and Soll, undated; Bonnett, 1926; Nelson, et al., 1949; Hewitt, 1952; Chiarappa, 1959, and 1959a; and Hewitt and Jensen, 1965). The Black Measles disease can occur on wine, table, and raisin grapes in most areas of California, although it is most prevalent in the interior valleys which have consistently high summer temperatures. The disease is most noticeable in the white and light-colored varieties; table grape growers in the San Joaquin Valley suffering the most serious losses (Hewitt and Jensen, 1965; and Moller and Soll, undated). Generally, vines that are 8 to 10 years or older are affected.

Either the fruit, vine, or both, may be affected. One or more shoots, or the entire vine, may be diseased. Symptoms often are present on a vine 1 year and absent the next. Some vines may show symptoms several years in succession, and be randomly distributed throughout the vineyard. Symptoms are always correlated with an intensive wood rot in the vine. Black Measles appears to be caused by toxins (likely oxidative enzymes) released by one or more fungus species which invade the rotting wood (Chiarappa, 1959). Species of fungi in the genera Fomes, Cephalosporium, and Stereum (Phellinus) are most frequently implicated in the literature (Chiarappa, 1959, and 1959a; and Moller and Soll, undated). Rotting trunks of vines are the likely site for production of the fungus fruiting bodies, whose spores invade the live plants through unhealed wounds. As wood rot develops over the years, the toxins are apparently transported to other portions of the vines. Estimated annual volume losses of fresh market grapes range from 1.5 to 5% with an average level of about 3%. Individual vineyards may suffer up to 35% loss of table grapes and 25% loss in wine and raisin grapes (Christensen, 1978). Control on fresh market grapes is economical when about 3 to 4% of the vines are diseased (Hewitt, 1978).

Dead-Arm, so-called because of the dead arms sometimes associated with this disease, is caused by the fungus Phomopsis viticola Sacc. (Leavitt, undated; and Hewitt, 1971). It also causes black necrotic spots on leaves, leaf petioles, canes, and flower cluster stems, blighting of shoots and canes, and poor fruit quality and storage life. It occurs in the San Joaquin Valley of California and is most serious on the table and raisin grapes. Hewitt (1971) estimated that, in 1971, about 350,000 acres of vineyards (about 70% of California's acreage) were infected and Dead Arm was a serious disease on about 120,000 acres. Most recent estimates (Kasimatis, 1979) are about 40,000 acres affected by Dead-Arm. It was particularly severe in 1978 (Kissler, 1979).

Black Measles appears in severe and mild forms. The severe form usually occurs early in the growing season (May-June) and is characterized by sudden apical dieback of shoots, accompanied by leaf dropping and shriveling, bronzing, and drying of fruit clusters. Leaves remaining on the vines show necrosis and bronzing. In extremely severe cases, diseased shoots may completely die. The more common mild form may occur on all California vineyards, with symptoms developing throughout the growing season. Leaf symptoms are highly variable and consist of chlorotic and bronzed areas. The fruit may have dark, purple spots scattered throughout the outside of the berry. Affected grapes of certain varieties such as Emperor, Red Malaga, and Thompson Seedless have a slightly pungent, aromatic, and characteristic flavor. Affected clusters are worthless as table fruit regardless of variety (Hewitt, 1971).

Methods of Application

Sodium arsenite solution (43.4% NaAsO_2 in 30-gallon drums) is diluted (usually 3 qt./100 gallons water or about 3 pounds As/100 gallons) in a closed-system apparatus. California law presently requires employees, but not owners, to use closed systems for transfer and dilution of chemicals that have a poison label (Yagi, 1979). From 100 to 300 gallons per acre are applied (3 to 9 pounds As per acre) depending on size of vines and number of vines per acre. Some growers use a standard wind machine sprayer (Yagi, 1979), which would present some drift hazard if the applicator were not protected by an enclosed cab and proper clothing and face mask. Most growers use high-pressure sprayers with no air blower. Many are specially built sprayers that use dual nozzles on an extension boom that minimizes drift problems.

Application is made during the dormant season to the entire head or under-branch part of the vines. Treatment of individual infected vines has proven ineffective, and therefore the entire vineyard must be treated.

Use Patterns and Efficacy

Table 72 gives the acreage, production, and value of grapes in 1977, 1978, and estimates for 1979. The alternative usage of table and raisin grapes for wine makes estimates of actual production and income per acre difficult. It would appear from evaluating production, yield, and acreage statistics that about 50% of the table and raisin varieties actually are crushed for wine.

Acreage figures by region and variety are not directly available; however, production data are available and can be used to verify wine variety acreage. Table 73 shows that the San Joaquin Valley, which has the highest incidence of Black Measles, has nearly all of the table and raisin grape acreage and 74.7% of the wine grape production. Wine variety grapes are rarely treated for measles control. A very small percentage of the Thompson Seedless grape acreage dried for raisins might be sprayed.

Only Thompson Seedless grapes for fresh table use are commonly sprayed. Thus, probably about half of the 60,000 acres of table grapes would be treated yearly.

Table 72.--Acres, production, and value of grapes, California, 1977-1979

Type of Grape	Bearing Acres ^a	Yield Per Acre	Production ^b	Value Per Ton	Value Per Acre	Value of Production ^b
		Tons	1,000 Tons	- - Dollars - - -		1,000 Dollars
Grapes, all:						
1977	621,730	6.41	3,986	190 ^d	1,218	757,909 ^c
1978	616,247	6.52	4,017 ^c	232 ^d	1,513	874,307 ^c
1979	616,247 ^e	7.29 ^f	4,493	226 ^{e,f}	1,648	1,016,261
1977-79	618,075	6.74 ^f	4,165	216 ^{e,f}	1,456	882,826
Raisin type:						
1977	242,220	7.99	1,935	182 ^f	1,454	353,112
1978	240,348	7.98	1,918 ^c	229 ^f	1,827	381,641 ^c
1979	240,348 ^e	9.57 ^f	2,300	232 ^{f,g}	2,220	533,342
1977-79	240,972	8.51 ^f	2,051	215 ^{f,g}	1,830	422,698
Table type:						
1977	64,330	7.59	488	269	2,042	131,272
1978	62,245	6.31	393	342	2,158	134,406
1979	62,245 ^e	6.64 ^f	413	303 ^f	2,012	125,139
1977-79	62,940	6.85 ^f	431	302 ^f	2,069	130,272
Wine type:						
1977	315,180	4.96	1,563	175	868	273,525
1978	313,654	5.44	1,706	210	1,142	358,260
1979	313,654 ^e	5.68 ^f	1,780	201 ^f	1,142	357,780
1977-79	314,163	5.36 ^f	1,683	196 ^f	1,051	329,855

^a California Crop and Livestock Rep. Serv., "California Grapes, Raisins, and Wine," 1978, Table 2, page 2, October 1979 (CCLRS, 1978a and 1979b).

^b Noncitrus Fruits and Nuts Annual Summary (USDA, 1980; and CCLRS, 1979).

^c Raisin and all grape total production includes 248,000 fresh tons (55,000 dry tons) laid for raisins, but not harvested due to severe weather damage. Value of lost raisins is not included in value of production. Data presentation is identical to published data.

^d Calculated using 1978 harvested production (see footnote c); i.e., \$874,307,000 ÷ [4,017,000 - 248,000 = 3,769,000] = \$231.97.

^e Bearing acres in 1979 assumed to be same as bearing acres in 1978 because SRS estimate of bearing acres in 1979 will not be released until June 1980.

^f Weighted average.

^g Calculated using 1978 harvested production (see footnote c); i.e., \$381,641,000 ÷ [1,918,000 - 248,000 = 1,670,000] = \$228.53.

Table 73.--Regional California projected grape production^a

Region	Year	Bearing Acres			Percent of production		
		Table	Raisin	Wine	Table	Raisin	Wine
North and South Coast	1975	0	--	47,000	0	0	19.3
	1979	--	--	107,875	--	--	--
San Joaquin Valley	1975	68,300	250,000	123,400	100	100	74.7
	1979	58,937	242,306	183,049	--	--	--
Other	1975	0	0	14,900	0	0	6.0
	1979	5,407	2,936	22,831	--	--	--

^a Garoyan, et al., 1975; and Moulton, 1979.

Table 74 summarizes establishment, production, and harvest costs for grapes. Establishment costs are similar except for the North Coast area. Production and harvest costs vary widely, depending on use and yield.

Hewitt (1978) estimates that from 3 to 20% of the susceptible acreage is subject to sodium arsenite treatment yearly. Based on 1978 figures, this would be about 16,000 to 54,000 acres, utilizing (at an average application rate of 6 pounds per acre) from 100,000 to 324,000 pounds As_2O_3 . In 1976-1977, Los Angeles Chemicals sold about 20,000 to 30,000 gallons of 43.5% sodium arsenite (80,000 to 120,000 pounds As_2O_3), but 1977-1978 has seen a sharp increase in use, estimated at 60,000 to 70,000 gallons (240,000 to 280,000 pounds As_2O_3) (Stephens, 1979). More sodium arsenite could have been sold in 1978-1979 if it had been available; the increased demand is apparently due to a much higher incidence of Dead-Arm and Black Measles because of repeated spring rains in 1978 (Christensen, 1978; and Stephens, 1979). This use is much greater than the total estimated agricultural use of sodium arsenite in PD-1 (Federal Register, 1978).

Treatment for Black Measles by spraying with sodium arsenite in the dormant season is generally considered an effective (>80%) control (Nelson, et al., 1949; Hewitt, 1970, 1971, and 1978; Christensen, 1978; and Hewitt and Jensen, 1965). Moller and Soll (undated), however, feel that control is erratic and Soll (1978) has reservations about the efficacy of sodium arsenite. These questions can only be resolved by future research. Nevertheless, the industry continues to use this material; thus economic benefits must be assumed to occur.

Early treatment with sodium arsenite can damage grapevines (Nelson, et al., 1949), particularly if leaf scars on varieties such as Thompson Seedless have not healed and are sprayed directly. Also, yield reductions have been noted from treating vineyards with sodium arsenite for more than 2 consecutive years (Hewitt and Jensen, 1965).

Exposure Analysis

The sodium arsenite solution (43.4% NaAsO_2 , 3.4 pounds As/gal.) commonly is delivered in 30-gallon drums. Because it carries a poison label, California law

Table 74.--Sample 1978 costs of grape establishment production and harvest

Region and Type of Grape	Establishment	Production		Harvest
	Dollars/Acre, 3 yr	Yield, Tons	Dollars/ Ton	Dollars/ Ton
<u>North Coast Wine</u> ^a				
Cane-pruned	5,680	4	465	75
Head-trained	5,680	4	295	54
<u>San Joaquin-Thompson Seedless</u> ^b				
Raisins	2,533	2.2	381	176
Wine	2,533	7.8	108	4
Table	2,981	6.0	227	448
<u>San Joaquin-Emperor Table</u> ^c	3,117	5.25	210	435
<u>San Joaquin-Wine</u> ^d				
High yield varieties	2,754	11	79	18
Moderate yield varieties	2,754	8	108	13

^a Bowers, et al., 1978.

^b Christensen, et al., 1978, 1978a, 1978b; and Swanson, et al., 1978.

^c Christensen, et al., 1978c; and 1978d.

^d Christensen, et al., 1978e; and 1978f.

requires employees to use a closed system for transfer and dilution of the solution, eliminating the possibility of direct contact (Yagi, 1979). Vineyard owners do not need to follow this rule, but because most vineyards are relatively large operations, little direct human contact with the solution should occur. Further, many growers use tractors with enclosed cabs and enforce the use of proper clothing. Thus, applicator contact is probably minimal. In 1969, only 12 lead or As-related occupational diseases attributed to pesticides or other agricultural chemicals from a total of 1,493 cases reported (CDPH, 1970). All 12 of these cases occurred during spring-summer, when sodium arsenite would not have been used on grapevines.

Inasmuch as the actual rate of As applied is relatively low (4 to 9 pounds per acre per treatment), and treatment is required only once every 4 to 7 years, the risks of environmental exposure at harmful levels should be minimal. Interestingly, some wineries in California do not purchase grapes treated with sodium arsenite (Moller and Soll, undated).

Fate in the Environment

Sodium arsenite is applied to arable soils, and its fate is therefore essentially that of arsenate (see Volume I, Chapter 4). Transport through runoff of topsoil containing elevated levels of arsenate is unlikely because most California vineyards are on level ground. The possibility of changes in land use (e.g., suburbs on As-treated vineyard land) must be considered, but at the levels of As used environmental problems would seem unlikely.

Alternatives

No alternatives for control of Black Measles are registered or in the experimental stage. Diseased vines could be removed by hand, but this is not economically feasible (Hewitt, 1971). Dead Arm (Phomopsis) can be controlled with captan, but this treatment does not seem to be effective in severe outbreaks (Hewitt, 1971; and EPA, 1976b), although continued treatment with captan for 2 to 3 years may be sufficient (Hewitt, 1971). Other alternatives for Phomopsis control include folpet and Dithane M-45. These must be applied as foliar treatments in early spring (Thomson, 1978; Leavitt, undated; and Kissler, 1979). The dinitro compound, dinoseb (Premerge®), is a registered alternative for dormant eradication of Phomopsis.

When more is known about the organisms responsible for Black Measles and the mechanisms leading to the symptomatic damage, alternate chemical and/or management strategies may be developed (Soll, 1978).

Summary of Biological Analysis—Sodium Arsenite

Non-Selective Herbicide and Tree Killer

Sodium arsenite is normally applied as diluted solutions by sprinkling can. Applicator exposure is minimal because the concentrate is formulated as a liquid, which is further diluted with water. Little exposure to the environment is likely with soil semi-sterilization uses.

Sodium arsenite is an effective soil semi-sterilant for weed control and for tree-stump control. Numerous alternatives are available, however, which have lower toxicity and have less potential environmental impact. No benefits over the alternatives seem apparent.

Subterranean Termite Control

Sodium arsenite is applied in trenches as a water solution for the control of subterranean termites. Exposure is limited to the application, as the treated soil is covered over.

Several long-lasting alternatives are available for control of subterranean termites. There are no suitable substitutes to sodium arsenite, however, for certain specialty uses where organic vapors cannot be tolerated.

Grape Disease Control

Sodium arsenite is used to control Dead Arm and Black Measles in California grapes. It is applied as a directed dormant spray on 3 to 20% of the susceptible acreage yearly. Application is at a rate of 3 to 9 pounds As_2O_3 /acre. The concentrate is diluted in a closed system and exposure is limited to the application process. No exposure data are available, however. The low application rates should present little environmental problems, especially since any one field will only be treated once every 4 to 7 years.

A summary of testimonial letters solicited from growers in California is shown in Table 75. The responses are from professional extension workers, associations, and private individuals.

Table 75.--Summary of testimonial letters for the use of sodium arsenite in grape production in California^a

Name ^b	A/P/I ^c	1	2	3	4	5	6	7	8	9	10	
T. Hale	A	X	X	X	X	X	X		X			<u>Column Headings</u>
F. Merlo	I	X	X		X					X		1. No other material is available to control Black Measles.
H. L. Andris	P	X	X		X		X	X				2. Desire registration.
F. L. Jensen	P	X	X	X	X			X				3. Infected table grapes are unmarketable.
S. H. Ficklin	I	X	X									4. Black Measles causes a severe loss of grapes and/or income.
T. H. Aivazian	I	X	X	X		X						5. Black Measles appear sporadically.
J. G. Zaninovich	I	X	X		X						X	6. Black Measles will cut the life of the vineyard.
C. Elrich	I		X		X					X		7. Replant costs are high.
G. A. Zaninovich	I	X		X		X						8. Sodium arsenite has a limited environmental impact.
A. V. Zaninovich	I	X	X		X							9. Sodium arsenite gives good control of Black Measles.
M. B. Zaninovich	I				X						X	
W. J. Gamboni	I	X	X					X			X	10. Have seen no adverse effects on employees. ^d
J. Jakovich	I	X							X	X	X	
M. Caratan	I	X	X		X						X	
N. Zaninovich	I		X		X							
Total Responses (15)	12	12	4	10	3	2	3	2	3	5		

^a An X indicates they mentioned this item in their letter. A blank indicates no mention of this in their letter.

^b For more information on the respondents see references.

^c A = Association; P = Professional extension worker; I = Individual grower or farm manager.

^d Adverse effects observed would most likely be acute, not chronic.

Although sodium arsenite is effective for control of Dead-Arm, several alternatives exist; however, no alternatives to sodium arsenite for Black Measles control are currently available.

Economic Impact Analysis of Canceling Sodium Arsenite

Sodium Arsenite—Non-Selective Herbicide and Tree Killer

The list of alternatives to herbicide uses of sodium arsenite is extensive (Table 70), with the exception of use as a soil semi-sterilant under pavement. Many of the alternatives are highly efficacious and at least one of these is less expensive, suggesting that little or no impact would result from canceling these uses. Generally, the extent-of-use data are not known. It is known, however, that sodium arsenite use has not been widespread in the paving industry because there is also a highly effective alternative in sodium borate-chlorate. The cancellation of sodium arsenite use under pavement is unlikely to result in large impacts. Greater risk associated with dependence on a single chemical would be a result.

Sodium arsenite costs approximately \$12 per gallon (42.5% a.i.) and is applied at the rate of 1 gallon per 300 to 1,200 square feet (Besthoff, 1979). The chemical cost is 12 to \$40 per 1,000 square feet (all prices are suggested consumer prices). Sodium borate-chlorate is an equally effective alternative, costs \$62.25 per 100 pounds (Wackermann, 1979a), and is applied at the rate of 1/2 to 4 pounds per 100 square feet (Ritehoven, 1980). This alternative costs 3.11 to \$24.90 per 1,000 square feet, about half the cost of sodium arsenite. The chemical cost of treatment under pavement is near the higher figure of the above price ranges and may explain the limited use of such chemicals for control of weeds under pavement.

Sodium Arsenite—Subterranean Termite Control

No narrative (see summary, page 209).

Sodium Arsenite—Grape Disease Control

Introduction

Sodium arsenite is used to control two diseases of grapes, Black Measles and Phomopsis cane and leaf spot (Dead Arm) in the San Joaquin Valley of California. No alternatives for control of Black Measles are registered or in the experimental stage (Moller, 1979; and Jensen, 1979a). Diseased vines can be removed by hand, but this is neither economically feasible nor desirable because symptoms are highly erratic from year to year. Black Measles control is important on all grapes for fresh use, but is not as important on grapes to be used for wine or raisins. Phomopsis can be controlled with a mixture of dinoseb and oil (dormant), and can be effectively suppressed with captan, folpet, or Dithane M-45 (soon after budbreak) (Moller, 1979). Dinoseb would be the alternative of choice because it is used in the same manner and at the same time as sodium arsenite, which is used primarily on grapes in the San Joaquin Valley of California (Moller, 1979).

Methodology and Assumptions

1. This analysis examines the economic effect of the cancellation of sodium arsenite to control Black Measles and Phomopsis cane and leaf spot (Dead Arm) on grapes in California.

2. The analysis assumes that no new materials will be registered for control of Black Measles and Phomopsis cane and leaf spot for at least 6 years following cancellation of sodium arsenite.

3. Partial budgets, considering only materials and cultural practices that change, are used to estimate cost differences with and without sodium arsenite.

4. The 1977-79 weighted average acres, production, and value for grapes in California are assumed to represent the acres, production, and value of grapes that would occur in the analysis period.

5. Losses from not controlling Black Measles on table- and raisin-type grapes increase through time. An analysis period of 6 years is assumed adequate to reflect short-term losses due to the cancellation of sodium arsenite. Production losses of raisin-type grapes for raisins continue to increase through year 11 in this analysis. Thus, the 6-year summary does not represent maximum expected losses. A 7% discount rate is used to calculate present values of the losses occurring during these 6 years.

6. Consideration of longer term losses is limited to estimating the change in amortized investment costs due to shorter vineyard life without Black Measles control. A 7% amortization rate is used in this analysis.

7. It is assumed that 75% of raisin-type grapes treated with sodium arsenite are sold fresh as table grapes, and 25% are dried for raisins (Jensen, 1979a).

8. In practice, treatments for Black Measles on table- and raisin-type grapes for fresh market occur in the dormant period prior to the season when the individual grower expects a level of infestation of about 4% infested vines. This is assumed to occur once every 3 years in infested vineyards. Expected levels of infestation are estimated based on counts of vines with symptoms in the previous season. A sodium arsenite application usually reduces the level of infestation by about 2/3 or to around 1% (Jensen, 1979a). After treatment, the infestation begins to increase in an erratic manner. For this analysis, it is assumed that the infestation would increase in equal increments over the 3-year period that sodium arsenite gives protection (Jensen, 1979a). This assumption reflects the typical situation of maximum control of Black Measles in the treatment year and reduced control the following 2 years (Jensen, 1979a). Fruit cullage and/or fruit loss are highly correlated to the level of infestation in the vineyard (Jensen, 1979a). Thus, fruit cullage and/or fruit loss due to Black Measles are minimized in the treatment year and increase with the level of infestation the first and second years after treatment. This reflects a reduction in the protective effects or benefits from a sodium arsenite treatment 1 and 2 years after treatment.

In addition, it is assumed that the losses from Black Measles during the first 3-year treatment rotation after cancellation of sodium arsenite would equal the protective effect or benefit from sodium arsenite had it been used. During the second 3-year treatment period, 4 to 6 years after cancellation, an average protective effect of 3% was assumed (Moller, 1979; and Jensen, 1979a). This average effect is used because of the highly erratic nature of an uncontrolled Black Measles

infestation and the lack of test plot data reflecting the effects of uncontrolled Black Measles infestations (Jensen, 1979a).

Based on the above, the following efficacy schedule was estimated and is assumed to represent the progression of the effects of Black Measles on grapes utilized for table use (Jensen, 1979a). The percentages shown in the column "Protective Effect" are benefits of reduced cullage from the use of sodium arsenite to control Black Measles, or expected losses if sodium arsenite is canceled.

<u>Time Period</u>	<u>Vines Infested</u>	<u>Fruit Cullage or Loss^a</u>	<u>Protective Effect</u>
Treatment year	1%	0	3%
1 year later	2%	1%	2%
2 years later	3%	2%	1%
3 years later	retreat ^b or 4% + ^c	0 or 3% + ^c	3% ^c
4 years later	+ ^c	+ ^c	3% ^c
5 years later	+ ^c	+ ^c	3% ^c

^a Fifty percent of fruit affected goes to winery for crushing; 50% lost (no value). Utilization of infected grapes depends on level of infestation in vineyard, severity of symptoms, and method of packing (approximately 2/3 of fresh market grapes are field-packed and 1/3 shed-packed). Unless other problems that cause considerable fruit to be left unharvested exist in vineyards being field-packed, it is rarely economical to glean the measled grapes for crushing. In harvesting for shed packing, clusters with severe symptoms are left in the field. Clusters with mild or moderate symptoms are harvested, culled, and crushed.

^b A sodium arsenite application usually reduces the level of infestation by about 2/3 to around 1% (Jensen, 1979a).

^c Highly erratic. Individual vineyards may suffer infestations and output losses of 25-35%, with an average loss of 10% possible in a bad year. It is assumed that if the Black Measles infestations were left untreated for 4 or more years after cancellation of sodium arsenite, the resulting cullage losses would be at least 3% annually.

9. By using assumptions identical to those in statement number 8, except for time frame, the following efficacy schedule was prepared and is assumed to represent the progression of the effects of Black Measles on raisin-type grapes utilized for raisins (Jensen, 1979a). Again, the percentages shown in the column "Protective Effect" are benefits of the reduction in losses from the use of sodium arsenite to control Black Measles, or expected losses if sodium arsenite is canceled.

<u>Time Period</u>	<u>Vines Infested</u>	<u>Fruit Cullage or Loss^a</u>	<u>Protective Effect</u>
Treatment year	2%	0	1.25%
1 year later	3%	.25%	1.00%
2 years later	4%	.50%	.75%
3 years later	5%	.75%	.50%
4 years later	6%	1.00%	.25%
5 years later	retreat ^b or 7% + ^c	0 or 1.25% ^c	1.25% ^c
6 years later	+ ^c	+ ^c	1.25% ^c

^a All fruit lost (no value). In harvesting raisin grapes for raisins, all grapes are taken from vines and laid for drying. Grapes with moderate symptoms cannot be distinguished from other raisins after drying. Only those grapes with symptoms severe enough to cause splitting, decay, and/or complete drying are lost. It is assumed that 25% of the grapes with symptoms are affected severely enough to be lost in the process of drying for raisins (Jensen, 1979a). Thus, the losses associated with raisin grapes for raisins are much smaller than for fresh market, but are total losses.

^b A sodium arsenite application usually reduces the level of infestation by about 2/3 or to around 2% (Jensen, 1979a).

^c Highly erratic. Individual vineyards may suffer infestations of 25 to 35%, with associated raisin losses of 6 to 9%. Average raisin losses of 2.5% are possible in a bad year. It is assumed that if the Black Measles infestations were left untreated for 6 or more years, the resulting raisin losses would be at least 1.25% annually.

10. Raisin-type grapes for fresh market use and raisin-type grapes for raisins are managed very differently throughout the life of the vineyard (Jensen, 1979a). Therefore, it is assumed that vineyards of raisin-type grapes established and managed for fresh market could not shift to raisin production and vice versa.

11. It is assumed that sodium arsenite is essential for Black Measles control on 80,000 acres of table and raisin-type grapes managed for fresh market utilization and 6,300 acres of raisin-type grapes dried for raisins in the San Joaquin Valley of California (Moller, 1979; and Jensen, 1979a). Black Measles occur or have a potential to occur in all vineyards 8 years or older in the San Joaquin Valley; however, only 33,150 acres currently have a Black Measles problem severe enough to treat with sodium arsenite. Therefore, only these 33,150 acres are included in the short-term analysis.

12. A rate of discount of 7% was assumed appropriate for discounting the estimated future revenue losses and treatment cost savings without sodium arsenite back to a present value for year 1.

Current Use Practices

There are about 618,000 acres of all types of grapes in California (Table 72). Wine-type grapes (314,000 acres) predominate. Raisin-type grapes (241,000 acres) and table-type grapes (63,000 acres) produce greater yields and value per acre. Average

1977-79 yields for raisin-, table-, and wine-type grapes were 8.51 tons, 6.85 tons, and 5.36 tons, respectively. Total value of grapes in California averaged \$882.8 million in 1977-79 with raisin-, table-, and wine-type grapes averaging \$422.7 million, \$130.3 million, and \$329.9 million, respectively (Table 72). Sodium arsenite is most important on raisin-type and table-type grapes for fresh market. Raisin and table uses of grapes annually contributed \$76.8 million and \$102.4 million, respectively, to the total value of grapes in California in 1977-79 (Table 76).

Sodium arsenite is currently used for Black Measles and Phomopsis cane and leaf spot (Dead Arm) control on grapes in California. To simplify presentation of the data, analysis, and impacts, the discussion of Black Measles and Phomopsis is separated in this report.

Black Measles.--Sodium arsenite is essential for Black Measles control on 80,000 acres of table- and raisin-type grapes managed for fresh market utilization and 6,300 acres of raisin-type grapes dried for raisins in the San Joaquin Valley of California (Moller, 1979; and Jensen, 1979a). Black Measles occurs or has a potential to occur in all vineyards 8 or more years old in the San Joaquin Valley. Currently, less than half of the fresh market grape acreage has a Black Measles problem serious enough to treat with sodium arsenite. Sodium arsenite for Black Measles control is less important on the wine- and other raisin-type grapes.

About 10,000 acres of table- and raisin-type grapes are treated with sodium arsenite for Black Measles control annually (Table 77). Treatments give protection for 3 years on fresh market grapes and about 6 years on raisin-type grapes for raisins; therefore, about 33,150 acres are protected at any one time (Moller, 1979; and Jensen, 1979a). It is estimated that the 10,000 acres treated annually consist of 3,150 acres of raisin-type grapes for fresh market, 1,050 acres of raisin-type grapes to be dried for raisins, and 5,800 acres of table-type grapes for fresh market (Table 77). The raisin- and table-type grapes for fresh market are treated with 9 pounds arsenic¹⁵ per acre in 300 gallons of water (Jensen, 1979a). Raisin-type grapes for drying are treated with 6 pounds of As_2O_3 per acre in 200 gallons of water (Moller, 1979; and Jensen, 1979a). Application is usually by a three-man team, with two persons using hand-directed nozzles (Moller, 1979; and Jensen, 1979a).

Phomopsis.--An additional 5,000 acres of raisin- and table-type grapes are treated annually for Phomopsis control (Table 77). Phomopsis control requires annual treatments (Moller, 1979). Six pounds of As_2O_3 in 200 gallons of water are applied as a dormant spray (Moller, 1979). Method of application is the same as for Black Measles (Moller, 1979).

Estimated Use of Sodium Arsenite and Cost

Black Measles.--About 86,850 pounds of As_2O_3 are applied annually on raisin- and table-type grapes for fresh market use and raisin-type grapes for raisins (Table 77). About 34,650 pounds are used on raisin-type grapes and 52,200 pounds on table-type grapes. At the current price of As_2O_3 (\$6 per 4-pound gallon), the cost of sodium arsenite is \$9.00 per acre at a rate of 6 pounds, and \$13.50 per acre at a

15 Use figures will be expressed in terms of As_2O_3 , although sodium arsenite is the material used.

Table 76.--Utilization of grape production and average grower returns for grapes, California 1977-1979^a

Type of Grape	Production for Fresh Market			Production for Processing			Total Production		
	Tons	Value Per Ton ^b	Total Value	Tons	Value Per Ton ^b	Total Value	Tons	Value Per Ton ^{b,c}	Total Value ^c
	<u>1,000</u>	<u>Dollars</u>	<u>1,000 Dollars</u>	<u>1,000</u>	<u>Dollars</u>	<u>1,000 Dollars</u>	<u>1,000</u>	<u>Dollars</u>	<u>1,000 Dollars</u>
Grapes, all:									
1977	461	427	196,847	3,525	159	560,475	3,986	190	757,322
1978	412	483	198,996	3,357	201	674,757	3,769	232	873,753
1979	479	401 ^d	192,079	4,104	206 ^d	826,884	4,493	227 ^d	1,018,963
1977-79	451	435 ^d	195,974	3,632	189 ^d	687,372	4,083	216 ^d	883,346
Raisin type:									
1977	155	487	75,485	1,780	156	277,680	1,935	183	353,165
1978	155	500	77,500	1,515	201	304,515	1,670	229	382,015
1979	166	466 ^d	77,356	2,134	214 ^d	456,676	2,300	232 ^d	534,032
1977-79	159	483 ^d	76,780	1,810	191 ^d	346,290	1,968	215 ^d	423,071
Table type:									
1977	205	502	102,910	283	101	28,583	488	269	131,493
1978	192	552	105,984	201	142	28,542	393	342	134,526
1979	225	437 ^d	98,325	188	143 ^d	26,884	413	303 ^d	125,209
1977-79	207	495 ^d	102,406	224	125 ^d	28,003	431	303 ^d	130,409
Wine type:									
1977	101	183	18,483	1,462	174	254,388	1,563	175	272,871
1978	65	240	15,600	1,641	209	342,969	1,706	210	358,569
1979	88	187 ^d	16,456	1,692	202 ^d	341,784	1,780	201 ^d	358,240
1977-79	85	198 ^d	16,846	1,598	196 ^d	313,047	1,683	196 ^d	329,983

^a Noncitrus Fruits and Nuts Annual Summary (USDA, 1980, CCLRS, and 1979).^b Value per ton is derived by dividing total value by tons produced.^c Does not equal totals in Table 72 because of rounding errors in published data.^d Weighted average.

Table 77.--Current use and costs of sodium arsenite for Black Measles control on raisin- and table-type grapes, San Joaquin Valley, California^a

Type of Grape and Method of Utilization	Bearing Acres		Pounds As_2O_3^d		Material Cost Per Pound $\text{As}_2\text{O}_3^{c,e}$	Per-Acre Treatment Cost			Total Cost
	In Area ^b	Treated ^c	Per Acre ^c	Total		Materials	Application ^c	Total	
----- Dollars -----									
Raisin	237,438	4,200	--	34,650	1.50	--	15.00	27.38	114,975
Fresh market		3,150	9	28,350	1.50	13.50	15.00	28.50	89,775
Dried		1,050	6	6,300	1.50	9.00	15.00	24.00	25,200
Table	57,336	5,800	9	52,200	1.50	13.50	15.00	28.50	165,300
Total	294,774	10,000	--	86,850	1.50	--	15.00	28.03	280,275

^a San Joaquin Valley includes Fresno, Kern, Kings, Madera, Merced, San Joaquin, Stanislaus, and Tulare Counties.

^b CCLRS, 1979c.

^c Moller, 1979; and Jensen, 1979a.

^d This analysis is based on a sodium arsenite formulation of 43.4% NaAsO_2 per gallon, or 4 pounds of As_2O_3 per gallon (Moller, 1979).

^e Based on cost of \$6 per gallon for formulation described in footnote d (Moller, 1979).

rate of 9 pounds, plus an application cost of \$15.00 per acre (Table 77). Total expenditures for Black Measles control on raisin- and table-type grapes are \$280,275.

Phomopsis.--About 30,000 pounds of As_2O_3 are applied annually on raisin- and table-type grapes for Phomopsis control (Table 78). As_2O_3 treatment costs \$9 per acre for materials plus \$15 per acre for application. Total expenditures for Phomopsis control on raisin- and table-type grapes are \$120,000 (Table 78).

Alternatives to Sodium Arsenite

Black Measles.--At present, sodium arsenite is the sole effective material registered for Black Measles control on grapes in California (Moller, 1979; and Jensen, 1979a). No other materials have been found to be effective in many years of research, and no new materials are in the experimental stage. Diseased vines can be removed by hand, but this is not economically feasible or desirable because symptoms are highly erratic from year to year; i.e., there is a significant risk of removing vines unnecessarily.

Phomopsis.--This disease can be controlled with dinoseb plus oil (dormant), captan, folpet, or Dithane M-45 (soon after budbreak). Dinoseb plus oil would be the alternative usually chosen because it is used in the same manner and at the same time as sodium arsenite and is equally effective (Assessment Team). Dinoseb is applied at the rate of 8.25 pounds a.i. per acre plus 2.5 gallons of oil (Table 78). At the current cost of dinoseb (\$3.17 per pound), the cost of using dinoseb plus oil is \$28.65 per acre (\$26.15 for dinoseb and \$2.50 for oil), plus \$15.00 per acre for application. Total cost of the dinoseb plus oil treatment would be \$218,250 for the 5,000 acres currently treated. Carefully timed applications of protectant fungicides such as captan, Dithane M-45, and folpet applied during the early season growth stages offer effective suppression of Phomopsis; however, control is less predictable because proper timing of the use of these materials is unlikely from year to year.

Use Impacts

Black Measles.--The Black Measles disease can occur on wine-, table-, and raisin-type grapes in most areas of California, but it is most prevalent in the San Joaquin Valley, which has consistently high summer temperatures (Moller, 1979). The disease is most noticeable in the white and light-colored varieties. Table-grape growers in the San Joaquin Valley suffer the most serious losses. Vines that are 8 to 10 years or older are affected most often.

Infected vines are randomly distributed throughout vineyards and symptoms appear on different vines from year to year. Symptoms are always associated with an intensive wood rot in the vine trunk caused by fungi of several genera. The time between planting and removal of vineyards is shortened by 5 to 7 years if not treated. Severe infestations are characterized by sudden dieback of shoots, leaf drop, and drying of fruit clusters. Moderate symptoms include purplish to black speckling and mottling of the berries which may be reduced in size, sometimes cracking followed by rot. Spotted fruit on some varieties have a slightly pungent, aromatic, and very characteristic flavor (Chiarappa, 1959). Affected clusters are worthless for fresh use, but a portion of the clusters can be crushed for wine. It is assumed that 50% of the infected raisin- and table-type grapes for fresh market use go to a winery for crushing and 50% are lost (no value). It is also assumed that 25% of all infected raisin-type grapes grown for raisins are lost (Jensen, 1979a).

Table 78. Current use and costs of sodium arsenite and potential alternatives for Phomopsis control on raisin- and table-type grapes, San Joaquin Valley, California^a

Alternative Treatment	Bearing Acres		Active Ingredient			Material Cost Per Unit a.i. ^c	Per Acre Treatment Cost			Total Cost	Increased Cost of Using Alternative
	In Area ^b	Treated ^c	Unit	Per Acre ^c	Total		Materials	Application ^c	Total		
----- Dollars -----											
Sodium arsenite ^d	294,774	5,000	lbs	6	30,000	1.50 ^e	9.00	15.00	24.00	120,000	
Dinoseb and oil	294,774	5,000		NA	NA	NA	28.65	15.00	43.65	218,250	98,250
Dinoseb		5,000	lbs	8.25	41,250	3.17 ^f	26.15				
Oil		5,000	gal	2.5	12,500	1.00 ^g	2.50				

^a San Joaquin Valley includes Fresno, Kern, Kings, Madera, Merced, San Joaquin, Stanislaus, and Tulare Counties.

^b CCLRS, 1979c.

^c Moller, 1979.

^d This analysis is based on a sodium arsenite formulation of 43.4% NaAsO₂ per gallon, or 4 pounds of As₂O₃ per gallon (Moller, 1979).

^e Based on cost of \$6 per gallon for formulation described in footnote d (Moller, 1979).

^f Based on cost of \$9.50 per gallon for 3 pound a.i. of dinoseb per gallon (Moller, 1979).

^g Moller, 1979.

Control with sodium arsenite is economical on table- and raisin-type grapes for fresh use when about 3 to 4% of the vines are diseased. On raisin-type grapes for raisins, control is economical when about 6 to 7% of the vines are diseased (Moller, 1979; and Jensen, 1979a). Sodium arsenite applied to a typical Black Measles infestation gives 50 to 75% control (or an assumed 2/3 reduction in infestation); i.e., a 3 to 4% infestation in a vineyard managed for fresh market in the treatment year is reduced to a 1% infestation after treatment. Sodium arsenite rarely eliminates a Black Measles infestation, but gives effective control for random length periods. Length of control is highly variable from vineyard to vineyard and may be related to weather and other factors. For this analysis, average efficacy schedules were estimated by viticulturists and assumed to represent the progression of the effects of Black Measles on grape yield and quality. These efficacy schedules and supporting assumptions are presented in methodology and assumption statements 7 and 8.

Cullage and yield losses on table- and raisin-type grapes for fresh market and raisin-type grapes for raisins in the first scheduled treatment year and latter years are presented in Table 79. The losses are in terms of percent of increased cullage of fresh market grapes and percent of yield loss for raisin-type grapes for raisins due to Black Measles on impacted acres. Grape cullage and yield losses from Black Measles in tons per acre by year are estimated in Table 80, using the percent loss per acre per year in Table 79, and the 1977-79 average yield by type of grape from Table 72. Distribution of cull fresh market grapes between crush increase and total output loss is also shown. The distribution is based on the assumption that 50% of the affected raisin- and table-type grapes for fresh market go to the winery and 50% are lost. Application of the 1977-79 weighted average prices to these quantities results in estimated losses of 40 to \$116 per acre per year for raisin-type grapes for fresh market, 32 to \$96 per acre per year for table-type grapes for fresh market, and 4 to \$21 per acre per year for raisin-type grapes for raisins (Table 80).

By using the per-acre cullage losses in Table 80, the estimated decrease in the production of raisin-type and table-type grapes for fresh market is 2,037 tons the first year after cancellation (Table 81). These losses are estimated to continue to increase to 6,111 tons in year 6, for an accumulated loss of 24,447 tons over the first 6 years after cancellation. Similarly, the production of raisin-type grapes for raisins is estimated to decrease 116 tons the first year and increase to a loss of 452 tons the sixth year, for an accumulated loss of 1,702 tons over the first 6 years. Detailed calculations used in making these estimates are presented in Tables 82, 83, and 84. It should be noted that one-half of the estimated decrease in raisin- and table-type grape production for fresh market represents an increase in cull grapes for wine production.

Tables 85, 86, and 87 present the per-acre and total decreases in value of production by type of grape and by year of the treatment cycle. Both decreases in value of production from Tables 85, 86, and 87, and savings in treatment costs from Table 75, are summarized in Table 85 by type of grape. By subtracting savings in treatment costs from the decrease in value of production, net value loss is obtained. Net value loss on raisin grapes for fresh market is \$275,600 the first year without sodium arsenite, increasing to a \$1,006,400 loss in the sixth year (Table 85). Net value loss on table-type grapes for fresh market is \$391,500 the first year without sodium arsenite, increasing to a \$1,505,100 loss in the sixth year. On raisin-type grapes for raisins, a net cost savings of \$3,100 occurs the first year without sodium arsenite. In the second year, however, there is a net value loss of \$14,800, which increases to a \$61,100 loss in the sixth year (Table 88). Value of production of raisin grapes for raisins continues to decrease through year 11 (Table 89). Therefore, this 6-year summary does not represent maximum losses.

Table 79.--Cullage and yield losses of grapes for fresh market use and raisins due to Black Measles without sodium arsenite

Time Period	Grape Cullage and Yield Loss ^a		
	Table Type for Fresh Market ^b	Raisin Type for Fresh Market ^b	Raisin Type for Raisins ^c
	- - - - - Percent - - - - -		
Scheduled treatment year	3.0	3.0	1.25
1 year later	2.0	2.0	1.00
2 years later	1.0	1.0	.75
3 years later	3.0	3.0	.50
4 years later	+ ^d	+ ^d	.25
5 years later	+ ^d	+ ^d	1.25
6 years later	--	--	+ ^e
7 years later	--	--	+ ^e

- ^a On table- and raisin-type grapes for fresh market use, it is assumed that 50% of fruit affected goes to a winery for crushing and 50% is lost (no value). On raisin-type grapes for raisins, it is assumed that all affected fruit was lost (no value) (Jensen, 1979a).
- ^b Based on progression of infestation and fruit cullage losses presented in Statements 7 and 8 in the Methodology and Assumptions section.
- ^c Based on progression of infestation and fruit cullage losses presented in Statements 7 and 9 in the Methodology and Assumptions section.
- ^d Highly erratic--individual vineyards may suffer infestations and losses of 25 to 35% and an average loss of 10% is possible in a bad year. An estimated average loss of 3% was assumed representative for this analysis (Moller, 1979).
- ^e Highly erratic--individual vineyards may suffer infestations of 25 to 35% with associated raisin losses of 6 to 9%. Average raisin losses of 2.5% are possible in a bad year. An estimated average loss of 1.25% was assumed representative for this analysis (Moller, 1979).

Table 80.--Estimated per acre fresh grape cullage, crush increase, yield loss, and decrease in value for scheduled treatment and later years if sodium arsenite is canceled for Black Measles control on grapes

Time Period	Raisin-Type Grapes			Table-Type Grapes			Yield Loss of Raisin Type Grapes for Raisins ^c	Decrease in Value of Grapes ^b		
	Fresh Cullage ^a	Crush Increase	Yield Loss	Fresh Cullage ^a	Crush Increase	Yield Loss		Fresh Use		Raisins
								Raisin Type	Table Type	
	<u>Tons</u>							<u>Dollars</u>		
Scheduled treatment year	.26	.13	.13	.21	.105	.105	.11	116	96	21
1 year later	.17	.085	.085	.14	.07	.07	.09	76	64	17
2 years later	.09	.045	.045	.07	.035	.035	.06	40	32	11
3 years later	.26	.13	.13	.21	.105	.105	.04	116	96	8
4 years later	.26	.13	.13	.21	.105	.105	.02	116	96	4
5 years later	.26	.13	.13	.21	.105	.105	.11	116	96	21
6 years later	.26	.13	.13	.21	.105	.105	.11	116	96	21

^a Cullage loss calculated by multiplying estimated percent yield loss from Table 10-74 by 1977-79 weighted average yield from Table 73. Estimated yields are 8.51 tons for raisin-type grapes for fresh market and raisins, and 6.85 tons for table-type grapes for fresh market (Table 73). Cullage was then apportioned to an increase in crushing grapes and a decrease in yield on the basis that 50% of the affected fruit from table- and raisin-type grapes for fresh use goes to winery for crushing, and 50% is lost (no value), (Jensen, 1979a).

^b Changes in utilization times value per ton. Values from Table 74 are: fresh market raisin-type grapes, \$483; fresh market table-type grapes, \$495; and raisin-type grapes for raisins (fresh basis), \$191. Value for cull grapes for crushing is \$75 (Christensen et al., 1978b). Example calculation: $[\text{.26} \times \$483 = \$125.58] - [\text{.13} \times \$75 = \$9.75] = \115.83 .

Fresh basis (before drying). Effects of Black Measles on raisin-type grapes for raisins are assumed to be entirely a yield loss (no value), (Jensen, 1979a).

Table 81.--Estimated increase in cullage of fresh market grapes and decrease in production of raisin-type grapes for raisins, by year, for first 6 years after cancellation of sodium arsenite for Black Measles control

Year	Grapes for Fresh Market			Raisin Type Grapes for Raisins ^c	Total All Grapes
	Raisin Type ^a	Table Type ^b	Total		
	<div>Tons</div>				
1	819	1,218	2,037	116	2,153
2	1,355	2,030	3,385	210	3,595
3	1,639	2,436	4,075	273	4,348
4	1,639	2,436	4,075	315	4,390
5	1,922	2,842	4,764	336	5,100
6	2,457	3,654	6,111	452 ^d	6,563
Total	9,831	14,616	24,447	1,702 ^d	26,149

^a Taken from Table 82, Column 7.

^b Taken from Table 83, Column 7.

^c Taken from Table 84, Column 13.

^d Production of raisin type grapes for raisins continues to decrease through year 11 (Table 84). Therefore, this 6-year summary does not represent maximum expected losses.

Table 82.--Estimated decrease in production of raisin-type grapes for fresh market, by year, for first 6 years after cancellation of sodium arsenite for Black Measles control

Year	Acres in 3-Year Treatment Cycle ^a						Fresh Market Production Loss
	Block 1 ^b		Block 2 ^b		Block 3 ^b		
	Per-Acre Loss ^c	Total Loss ^d	Per-Acre Loss ^c	Total Loss ^d	Per-Acre Loss ^c	Total Loss ^d	
	----- Tons -----						
1	.26	819	--	--	--	--	819
2	.17	536	.26	819	--	--	1,355
3	.09	284	.17	536	.26	819	1,639
4	.26	819	.09	284	.17	536	1,639
5	.26	819	.26	819	.09	284	1,922
6	.26	819	.26	819	.26	819	2,457

^a An estimated 3,150 acres (Table 77) of raisin-type grapes for fresh market are sprayed for Black Measles each year for a total of 9,450 acres during the 3-year treatment cycle (Moller, 1979).

^b Each block represents the 3,150 acres that are scheduled to be treated once each 3 years.

^c Taken from Table 80, Column 1.

^d Per-acre production loss times 3,150 acres.

Table 83.--Estimated decrease in production of raisin-type grapes for fresh market, by year, for first 6 years after cancellation of sodium arsenite for Black Measles control

Year	Acres in 3-Year Treatment Cycle ^a						Fresh Market Production Loss
	Block 1 ^b		Block 2 ^b		Block 3 ^b		
	Per Acre Loss ^c	Total Loss ^d	Per Acre Loss ^c	Total Loss ^d	Per Acre Loss ^c	Total Loss ^d	
	----- Tons -----						
1	.21	1,218	--	--	--	--	1,218
2	.14	812	.21	1,218	--	--	2,030
3	.07	406	.14	812	.21	1,218	2,436
4	.21	1,218	.07	406	.14	812	2,436
5	.21	1,218	.21	1,218	.07	406	2,842
6	.21	1,218	.21	1,218	.21	1,218	3,654

^a An estimated 5,800 acres (Table 77) of table-type grapes for fresh market are sprayed for Black Measles each year for a total of 17,400 acres during the 3-year treatment cycle (Moller, 1979).

^b Each block represents the 5,800 acres that are scheduled to be treated once each 3 years.

^c Taken from Table 80, Column 4.

^d Per-acre production loss times 5,800 acres.

Table 84.--Estimated decrease in production of raisin-type grapes for raisins, by year, for 11 years after cancellation of sodium arsenite for Black Measles control

Year	Acres in 6-Year Treatment Cycle ^a												Raisin Production Loss
	Block 1 ^b		Block 2 ^b		Block 3 ^b		Block 4 ^b		Block 5 ^b		Block 6 ^b		
	Per-Acre Loss ^c	Total Loss ^d	Per-Acre Loss ^c	Total Loss ^d	Per-Acre Loss ^c	Total Loss ^d	Per-Acre Loss ^c	Total Loss ^d	Per-Acre Loss ^c	Total Loss ^d	Per-Acre Loss ^c	Total Loss ^d	
	----- Tons -----												
1	.11	115.5	--	--	--	--	--	--	--	--	--	--	115.5
2	.09	94.5	.11	115.5	--	--	--	--	--	--	--	--	210.0
3	.06	63.0	.09	94.5	.11	115.5	--	--	--	--	--	--	273.0
4	.04	42.0	.06	63.0	.09	94.5	.11	115.5	--	--	--	--	315.0
5	.02	21.0	.04	42.0	.06	63.0	.09	94.5	.11	115.5	--	--	336.0
6	.11	115.5	.02	21.0	.04	42.0	.06	63.0	.09	94.5	.11	115.5	451.5
7	.11	115.5	.11	115.5	.02	21.0	.04	42.0	.06	63.0	.09	94.5	451.5
8	.11	115.5	.11	115.5	.11	115.5	.02	21.0	.04	42.0	.06	63.0	472.5
9	.11	115.5	.11	115.5	.11	115.5	.11	115.5	.02	21.0	.04	42.0	525.0
10	.11	115.5	.11	115.5	.11	115.5	.11	115.5	.11	115.5	.02	21.0	598.5
11	.11	115.5	.11	115.5	.11	115.5	.11	115.5	.11	115.5	.11	115.5	693.0

^a An estimated 1,050 acres (Table 77) of raisin-type grapes for raisins are sprayed for Black Measles each year for a total of 6,300 acres during the 6-year treatment cycle (Jensen, 1979a).

^b Each block represents the 1,050 acres that are scheduled to be treated once each 6 years.

^c Taken from Table 80, Column 7.

^d Per-acre production loss times 1,050 acres.

Table 85.--Estimated decrease in value of production of raisin-type grapes for fresh market, by year, for first 6 years after cancellation of sodium arsenite for Black Measles control

End of Year	Value for Acres in 3-Year Treatment Cycle ^a						Total Value of Loss	Net Present Value of Loss ^e
	Block 1 ^b		Block 2 ^b		Block 3 ^b			
	Per Acre Loss ^c	Total Loss ^d	Per Acre Loss ^c	Total Loss ^d	Per Acre Loss ^c	Total Loss ^d		
	<u>Dollars</u>	<u>1,000 Dollars</u>	<u>Dollars</u>	<u>1,000 Dollars</u>	<u>Dollars</u>	- - - <u>1,000 Dollars</u> - - -		
1	116	365.4	--	--	--	--	365.4	341.5
2	76	239.4	116	365.4	--	--	604.8	528.3
3	40	126.0	76	239.4	116	365.4	730.8	596.6
4	116	365.4	40	126.0	76	239.4	730.8	557.5
5	116	365.4	116	365.4	40	126.0	856.8	610.9
6	116	365.4	116	365.4	116	365.4	1,096.2	<u>730.5</u>
								3,365.3

^a An estimated 3,150 acres (Table 77) of raisin-type grapes for fresh market are sprayed for Black Measles each year for a total of 9,450 acres during the 3-year treatment cycle (Moller, 1979).

^b Each block represents the 3,150 acres that are scheduled to be treated once each 3 years.

^c Taken from Table 80, Column 8.

^d Per-acre value loss times 3,150 acres.

^e Present value of loss calculated using 7% discount factor.

Table 86.--Estimated decrease in value of production of table-type grapes for fresh market, by year, for first 6 years after cancellation of sodium arsenite for Black Measles control

End of Year	Value for Acres in 3-Year Treatment Cycle ^a						Total Value of Loss	Net Present Value of Loss ^e
	Block 1 ^b		Block 2 ^b		Block 3 ^b			
	Per Acre Loss ^c	Total Loss ^d	Per Acre Loss ^c	Total Loss ^d	Per Acre Loss ^c	Total Loss ^d		
	Dollars	1,000 Dollars	Dollars	1,000 Dollars	Dollars	- - - 1,000 Dollars - - -		
1	96	556.8	--	--	--	--	556.8	520.4
2	64	371.2	96	556.8	--	--	928.0	810.6
3	32	185.6	64	371.2	96	556.8	1,113.6	909.0
4	96	556.8	32	185.6	64	371.2	1,113.6	849.6
5	96	556.8	96	556.8	32	185.6	1,299.2	926.3
6	96	556.8	96	556.8	96	556.8	1,670.4	<u>1,113.1</u> 5,129.0

^a An estimated 5,800 acres (Table 77) of table-type grapes for fresh market are sprayed for Black Measles each year for a total of 17,400 acres during the 3-year treatment cycle (Moller, 1979).

^b Each block represents the 5,800 acres that are scheduled to be treated once each 3 years.

^c Taken from Table 80, Column 9.

^d Per-acre value loss times 5,800 acres.

^e Present value of loss calculated using 7% discount factor.

Table 87.--Estimated decrease in value of production of raisin-type grapes for raisins, by year, for first 11 years after cancellation of sodium arsenite for Black Measles control

End of Year	Value for Acres Treated in 6-Year Treatment Cycle ^a												Total Value of Loss	Net Present Value of Loss ^e
	Block 1 ^b		Block 2 ^b		Block 3 ^b		Block 4 ^b		Block 5 ^b		Block 6 ^b			
	Per-Acre Loss ^c	Total Loss ^d	Per-Acre Loss ^c	Total Loss ^d	Per-Acre Loss ^c	Total Loss ^d	Per-Acre Loss ^c	Total Loss ^d	Per-Acre Loss ^c	Total Loss ^d	Per-Acre Loss ^c	Total Loss ^d		
	<u>Dollars</u>	<u>1,000 Dollars</u>	<u>Dollars</u>	<u>1,000 Dollars</u>	<u>Dollars</u>	<u>1,000 Dollars</u>	<u>Dollars</u>	<u>1,000 Dollars</u>	<u>Dollars</u>	<u>1,000 Dollars</u>	<u>Dollars</u>	- - - - <u>1,000 Dollars</u> - - - -		
1	21	22.1	--	--	--	--	--	--	--	--	--	--	22.1	20.7
2	17	17.9	21	22.1	--	--	--	--	--	--	--	--	40.0	34.9
3	11	11.6	17	17.9	21	22.1	--	--	--	--	--	--	51.6	42.1
4	8	8.4	11	11.6	17	17.9	21	22.1	--	--	--	--	60.0	45.8
5	4	4.2	8	8.4	11	11.6	17	17.9	21	22.1	--	--	64.2	45.8
6	21	22.1	4	4.2	8	8.4	11	11.6	17	17.9	21	22.1	86.3	57.5
7	21	22.1	21	22.1	4	4.2	8	8.4	11	11.6	17	17.9	86.3	53.7
8	21	22.1	21	22.1	21	22.1	4	4.2	8	8.4	11	11.6	90.5	52.7
9	21	22.1	21	22.1	21	22.1	21	22.1	4	4.2	8	8.4	101.0	54.9
10	21	22.1	21	22.1	21	22.1	21	22.1	21	22.1	4	4.2	114.7	58.3
11	21	22.1	21	22.1	21	22.1	21	22.1	21	22.1	21	22.1	132.6	63.0
														529.4

^a An estimated 1,050 acres (Table 77) of raisin-type grapes for raisins are sprayed for Black Measles each year for a total of 6,300 acres during the 6-year treatment cycle (Jensen, 1979a).

^b Each block represents the 1,050 acres that are scheduled to be treated once each 6 years.

^c Taken from Table 80, Column 10.

^d Per-acre value loss times 1,050 acres.

^e Present value calculated using 7% discount factor.

Table 88.--Estimated decrease in value of production, savings in treatment cost, and net loss by type of grape, by year, for first 6 years after cancellation of sodium arsenite for Black Measles control

End of Year	Fresh Market Grapes						Raisin Type Grapes for Raisins		
	Raisin Type			Table Type			Decrease in Value of Production ^e	Savings in Treatment Cost ^b	Net Loss ^c
	Decrease in Value of Production ^a	Savings in Treatment Cost ^b	Net Loss ^c	Decrease in Value of Production ^d	Savings in Treatment Cost ^b	Net Loss ^c			
	1,000 Dollars								
1	365.4	89.8	275.6	556.8	165.3	391.5	22.1	25.2	-3.1
2	604.8	89.8	515.0	928.0	165.3	762.7	40.0	25.2	14.8
3	730.8	89.8	641.0	1,113.6	165.3	948.3	51.6	25.2	26.4
4	730.8	89.8	641.0	1,113.6	165.3	948.3	60.0	25.2	34.8
5	856.8	89.8	767.0	1,299.2	165.3	1,133.9	64.2	25.2	39.0
6	1,096.2	89.8	1,006.4	1,670.4	165.3	1,505.1	86.3	25.2	61.1 ^f
Total	4,384.8	538.8	3,846.0	6,681.6	991.8	5,689.8	324.2	151.2	173.0 ^f

^a Taken from Table 85, Column 7.

^b Taken from Table 77, Column 9.

^c Decrease in value of production minus savings in treatment costs.

^d Taken from Table 86, Column 7.

^e Taken from Table 87, Column 13.

^f Value of production continues to decrease through year 11 (Table 87). Therefore, this 6-year summary does not represent maximum expected losses.

Table 89.--Estimated increase in amortized investment costs resulting from the cancellation of sodium arsenite for Black Measles control on grapes, San Joaquin Valley, California

Type of Grape and Alternative Treatment	Protected Bearing Acres ^a	Vineyard Bearing Life and Amortization Period ^b	Vineyard Establishment Cost Per Acre ^c		Increase Per Year Amortized Investment cost	
			Total	Annual Amortized ^d	Per Acre	Total
		<u>Years</u>	<u>Dollars</u>			
<u>Raisin:</u>						
Sodium arsenite	15,750 ^e	32	2,981 ^f	236		
No treatment	15,750 ^e	26	2,981 ^f	252	16	252,000
<u>Table:</u>						
Sodium arsenite	17,400 ^g	32	3,117 ^h	246		
No treatment	17,400 ^g	26	3,117 ^h	264	18	313,200
Total	33,150	NA	NA	NA	NA	565,200

^a See footnote a in Tables 82, 83, and 84.

^b Moller, 1979. Bearing life and amortization period is estimated vineyard life minus 3-year establishment period.

^c Per-acre vineyard establishment costs defined as net costs incurred during 3-year establishment period. Includes an allowance for partial crop of fruit sold for juice the third year.

^d Total establishment cost amortized using an interest rate of 7% or an amortized factor of .08456 for 26 years and .07907 for 32 years; i.e., .07907 X \$2,981 = \$235.71 (Selby, 1967).

^e 9,450 acres of raisin-type grapes for fresh market and 6,300 acres of raisin-type grapes for raisins. See Tables 82, 84, 85, and 87.

^f Christensen, *et al.*, 1978.

^g From Tables 76 and 79.

^h Christensen, *et al.*, 1978a.

To accumulate these expected net revenue losses, it is necessary to express each year's loss in terms of value as of a base year. This is accomplished by discounting the estimated future revenue losses and treatment cost savings without sodium arsenite back to a present value for year 1, using a rate of discount of 7%. Thus, the loss of production value for all grapes, increased cullage, and reduced yield due to Black Measles is estimated to have a present value of \$8.7 million over the 6 years (Table 90). The present value of cost savings from not treating with sodium arsenite for the same period is estimated to be \$1.3 million. Subtracting cost savings from change in value of production results in a grower revenue impact of \$7.4 million the first 6 years after sodium arsenite is canceled (Table 90). These impact estimates assume *ceteris paribus* conditions in the California grape industry.

Table 90.--Estimated decrease in value of production, savings in treatment cost, and net loss on a current and present value basis for all grapes, by year, for the first 6 years after cancellation of sodium arsenite for Black Measles control

End of Year	Current Value			Present Value ^a		
	Decrease in Value of Production ^b	Savings in Treatment Cost ^c	Net Loss ^d	Decrease in Value of Production ^b	Savings in Treatment Cost ^c	Net Loss ^e
----- 1,000 Dollars -----						
1	944.3	280.3	664.0	882.5	262.0	620.5
2	1,572.8	280.3	1,292.5	1,373.7	244.8	1,128.9
3	1,896.0	280.3	1,615.7	1,547.7	228.8	1,318.9
4	1,904.4	280.3	1,624.1	1,452.9	213.8	1,239.1
5	2,220.2	280.3	1,939.9	1,583.0	199.9	1,383.1
6	2,852.9	280.3	2,572.6	1,901.0	186.8	1,714.2
Total	11,390.6	1,681.8	9,708.8	8,740.8	1,336.1	7,404.7

^a Present value calculated using 7% discount factor.

^b Sum of Columns 1, 4, and 7, Table 88.

^c Sum of Columns 2, 5, and 8, Table 88.

^d Column 1 minus Column 2.

^e Column 4 minus Column 5.

Additional loss resulting from the cancellation of sodium arsenite would be a shorter average bearing life of vineyards. With Black Measles control, it is estimated that a vineyard will have an average bearing life of 32 years. Without Black Measles control, the life would probably be reduced 5 to 7 years on the sodium arsenite-treated acreage (Moller, 1979). In the short run, costs associated with this change in vineyard bearing life are difficult to measure because of the lack of data on previous investment patterns and age distribution of existing vineyards. Effects of the shorter vineyard bearing life more appropriately fall into a long-run analysis. As data required for either a short- or long-run analysis are unavailable, it is assumed that all treated acres are of equal age and only amortized establishment costs change; i.e., the shorter bearing life of vineyards without sodium arsenite results in establishment costs being spread over fewer years, resulting in a higher annual cost.

It must be noted that the change in amortized costs estimated by this procedure is only a proxy for actual cost changes and cannot be added to the present value of impacts previously discussed. These amortized costs represent an estimate of increased annual fixed cost that growers can expect in the future without sodium arsenite or an equal alternative.

Table 91.--Estimated increase in amortized net income foregone during establishment period resulting from the cancellation of sodium arsenite for Black Measles control on grapes, San Joaquin Valley, California

Area	Fresh Market Grapes		Raisin Type
	Raisin-Type	Table-Type	Grapes for Raisins
	----- Dollars -----		
Per-acre:			
Gross value	3,090 ^a	2,673 ^b	1,625 ^c
Production costs	2,694 ^d	2,376 ^e	1,072 ^f
Net income	396	297	553
Per-acre net income foregone during 3-year establishment period:			
Amortized net income foregone if vineyard had 32-year bearing life	1,271 ^g	953 ^g	1,775 ^g
Amortized net income foregone if vineyard has 26-year bearing life	100 ^h	75 ^h	140 ^h
Amortized net income foregone if vineyard has 26-year bearing life	107 ^h	81 ^h	150 ^h
Annual increase in net income foregone without sodium arsenite	7	6	10
Protected acres:			
Total increase in amortized net income foregone	9,450 ⁱ	17,400 ⁱ	6,300 ⁱ
	85,050	104,400	63,000

^a Gross value is based on a yield of 8.51 tons--6.01 tons packed for fresh market and 2.5 tons of culls; i.e., (6.01 tons x \$483 = \$2,902.83) + (2.5 tons x \$75 = \$187.50) = \$3,090.33. Percent culls based on culls shown in budget cited in footnote b. Appropriateness of percent culls was confirmed by Moller, 1979 and Jensen, 1979a.

^b Gross value is based on a yield of 6.85 tons--5.14 tons packed for fresh market and 1.71 tons of culls; i.e., (5.14 tons x \$495 = \$2,544.30) + (1.71 tons x \$75 = \$128.25) = \$2,672.55. Percent culls based on culls shown in budget cited in footnote g. Appropriateness of percent culls was confirmed by Moller, 1979; and Jensen, 1979a.

^c Gross value is based on a yield of 8.51 tons; i.e., 8.51 tons x \$191 = \$1,625.41.

^d Christensen, *et al.*, 1978.

^e Christensen, *et al.*, 1978b.

^f Costs indexed to 1977-78 price base from Christensen, *et al.*, 1976.

^g Annual net income per acre times 3, plus 7% interest on accumulated foregone income.

^h Per-acre net income foregone amortized using an interest rate of 7% or an amortization factor of .08456 for 26 years and .07907 for 32 years (Selby, 1967).

ⁱ Taken from Table 89, Column 1 and footnote.

Establishment costs are of two types: 1) the 3-year investment for establishment and 2) the income foregone during the 3-year establishment period because of no or low grape yields. Annual amortized investment costs for raisin-type grapes for fresh market increase from \$236 per acre to \$252 per acre, or \$16 per acre, if vineyard bearing life is shortened from 32 to 29 years (Table 89). The amortized value of foregone income because of lost yields during establishment would change from \$100 per acre to \$107 per acre, or an increase of \$7 on an annual basis (Table 91). The two costs add to \$23 per acre to produce \$217,350 in increased annual establishment costs due to shorter vineyard life for the 9,450 acres of raisin-type grapes for fresh market that are protected.

Annual amortized investment costs for table-type grapes increase from \$246 per acre to \$264 per acre, or \$18 per acre (Table 89). The amortized value of foregone income because of lost yields during establishment would change from \$75 per acre to \$81 per acre, or an increase of \$6 on an annual basis (Table 91). The two costs add to \$24 per acre to produce \$417,600 in increased annual establishment costs due to shorter vineyard life for the 17,400 acres of table-type grapes for fresh market that are protected.

Annual changes in amortized investment costs for raisin-type grapes for raisins are the same as costs for fresh market grapes. The amortized value of foregone income because of lost yields during establishment would change from \$140 per acre to \$150 per acre, or an increase of \$10 on an annual basis (Table 91). The two costs add to \$26 per acre to produce \$163,800 in increased annual establishment costs due to shorter vineyard life for the 6,300 acres of raisin-type grapes for raisins that are protected.

Total annual increase in all amortized costs due to shorter vineyard bearing life for all grapes would be \$817,650 on the 33,150 acres protected. An estimated \$565,200 would be increased annual establishment costs, and \$252,450 would be from the increased amortized cost of lost production during the 3-year establishment period.

Phomopsis.--The use of sodium arsenite to control Phomopsis can be replaced by dinoseb plus oil to obtain equal control (Moller, 1979). Treatment with dinoseb plus oil costs \$43.65 per acre compared to \$24.00 per acre for sodium arsenite (Table 78). On the 5,000 acres treated annually with sodium arsenite, the increased costs are \$98,950 or \$19.65 per acre.

Average Per-Acre User Returns

The 1977-79 averages of the gross returns per acre for grapes were \$3,090 for raisin-type grapes for fresh market, \$2,673 for table-type grapes for fresh market, and \$1,625 for raisin-type grapes for raisins (Table 92). Production costs for the same period with sodium arsenite were \$2,705, \$2,387, and \$1,077, respectively. Thus, the average net returns were \$385 for raisin-type grapes for fresh market, \$286 for table-type grapes for fresh market, and \$550 for raisin-type grapes for raisins.

Without sodium arsenite for Black Measles control on the 33,150 acres currently treated, gross returns are expected to decrease by 4 to \$39 per acre the first year depending upon the type and use of the grapes. After 6 years, gross returns would decrease 14 to \$116 per acre (Table 92). Adjusting production costs for the savings from not using sodium arsenite, net returns for raisin-type grapes for fresh market would decrease from \$385 to \$280 per acre over the first 6 years. Net returns for table-type grapes for fresh market would decrease from 286 to \$201 per acre over the

Table 92.--Average annual per acre net returns with and without sodium arsenite on the 33,150 acres of California grapes currently treated with sodium arsenite for Black Measles control

Number of Years Without Sodium Arsenite	Per Acre				
	Gross Returns With Sodium Arsenite ^a	Loss of Gross Returns ^b	Gross returns Without Sodium Arsenite	Production Costs ^a	Net Returns
----- Dollars -----					
<u>Raisin-type grapes for fresh market:</u>					
0	3,090	0	NA	2,705 ^c	385
1	3,090	39	3,051	2,694	357
2	3,090	64	3,026	2,694	332
3	3,090	77	3,013	2,694	319
4	3,090	77	3,013	2,694	319
5	3,090	91	2,999	2,694	305
6	3,090	116	2,974	2,694	280
<u>Table-type grapes for fresh market:</u>					
0	2,673	0	NA	2,387 ^c	286
1	2,673	32	2,641	2,376	265
2	2,673	53	2,620	2,376	244
3	2,673	64	2,609	2,376	233
4	2,673	64	2,609	2,376	233
5	2,673	75	2,598	2,376	222
6	2,673	96	2,577	2,376	201
<u>Raisin-type grapes for raisins:</u>					
0	1,625	0	NA	1,077 ^d	548
1	1,625	4	1,621	1,072	549
2	1,625	6	1,619	1,072	547
3	1,625	8	1,617	1,072	545
4	1,625	10	1,615	1,072	543
5	1,625	10	1,615	1,072	543
6	1,625	14 ^e	1,611	1,072	539

^a Taken from Table 91.

^b Calculated by dividing protected acres into total value of losses shown in Tables 85, 86, and 87.

^c Includes cost of \$28.50 per acre for sodium arsenite treatment amortized over 3 years at 7% interest; i.e., $\$28.50 \times .38105 = \10.86 (Selby, 1967). See Table 75 for components of treatment costs.

^d Includes cost of \$24 per acre for sodium arsenite treatment amortized over 6 years at 7% interest; i.e., $\$24 \times .2098 = \5.04 (Selby, 1967).

^e Value of production of raisin-type grapes for raisins continues to decrease through year 11 (Table 87). Therefore, this 6-year summary does not represent maximum expected losses.

first 6 years. Net returns for raisin-type grapes for raisins would decrease from 550 to \$539 per acre in the sixth year.

Market and Consumer Impacts

In California, cullage and production losses of grapes during the first 6 years without sodium arsenite range from 0.52 to 1.55% of the total production of raisin-type grapes going into fresh market uses and 0.59 to 1.77% of the total production of table type grapes going into fresh market uses (Table 93). Losses of these magnitudes over the 6-year period are not expected to result in measurable price changes of fresh market grapes at the market or consumer level. The elasticity of demand for all grapes in California approaches unity as illustrated in the following data (Christensen, et al., 1978g).

<u>Market</u>	<u>Price Flexibility</u> ¹⁶	<u>Elasticity of Demand</u>
Farm	-0.981	-1.0194

This indicates that if the losses from the lack of control of Black Measles increase 1%, the price will decrease by approximately 0.981%. It should be noted that this is a point estimate of elasticity derived from annual data and applies to changes from one year to the next, not to changes over a 6-year period.

Limitations of the Analysis

The following limitations apply:

1. The assumed efficacy and performance schedules for sodium arsenite control of Black Measles used as the basis of this analysis are not well supported by test plot data; rather they are largely based on a consensus of agricultural specialists and viticulturists in the San Joaquin Valley of California. Use of the efficacy and performance schedules for Black Measles may over-simplify the actual variability of the disease.

2. This analysis presents effects of the lack of control of Black Measles for the first 6 years after sodium arsenite is canceled. Value of production of raisin-type grapes for raisins continues to decrease through year 11. Therefore, losses summarized in this report do not represent maximum expected losses.

3. Data needed to evaluate the costs of the 5- to 7-year change in expected vineyard life without Black Measles control are incomplete or non-existent. Users of the proxy analysis should recognize that the analysis does not reflect the difference between historical costs of existing vineyards and current cost of new vineyards. Therefore, the analysis may understate the cost of the shorter life of uncontrolled Black Measles infected vineyards.

4. It was assumed that sodium arsenite is essential for Black Measles control on 80,000 acres of table- and raisin-type grapes managed for fresh market utilization and 6,300 acres of raisin-type grapes dried for raisins in the San Joaquin Valley of California (Moller, 1979; and Jensen, 1979a); however, only 33,150 acres currently have a Black Measles problem severe enough to treat with sodium arsenite. Therefore,

¹⁶ The price flexibility is defined as the percentage change in price with respect to a 1% change in quantity.

Table 93.--Cullage and production losses for all grapes, by year, for first 6 years after cancellation of sodium arsenite for Black Measles control, California^a

Year	Grapes for Fresh Market			Raisin Type Grapes for Raisins ^d
	Raisin Type ^b	Table Type ^c	Total	
----- <u>Percent</u> -----				
1	0.52	0.59	0.56	0.01
2	0.85	0.98	0.92	0.02
3	1.03	1.18	1.11	0.03
4	1.03	1.18	1.11	0.03
5	1.21	1.37	1.30	0.03
6	1.55	1.77	1.67	0.04 ^e

^a Production declines by type and use of grape as shown in Table 83 divided by 1977-79 average production for California (Table 76, column 1).

^b Percent calculated using 1977-79 average production of raisin-type grapes for fresh market of 159,000 tons (Table 76, column 2).

^c Percent calculated using 1977-79 average production of table-type grapes for fresh market of 207,000 tons (Table 76, column 2).

^d Percent calculated using 1977-79 average production of raisin-type grapes dried for raisins of 1,087,000 tons (fresh basis), Noncitrus Fruits and Nuts Annual Summary (USDA, 1980).

^e Production losses of raisin-type grapes for raisins continue to decrease through year 11 (Table 84). Therefore, this 6-year summary does not represent maximum expected losses.

only the losses associated with the 33,150 acres currently treated are presented in this report.

Summary of Economic Impact Analysis of Canceling Sodium Arsenite

Sodium Arsenite—Non-Selective Herbicide and Tree Killer

- A. USE: Contact herbicide, soil semi-sterilant, and tree control.
- B. PLANTS CONTROLLED: Non-selective herbicide.

C. ALTERNATIVES:

Chemical: Many alternatives for all uses except weed control under pavement, for which only two alternatives have been identified: sodium TCA and sodium borate-chlorate.

Non-chemical: Varies according to specific use but usually involves a chopping, mowing, or tilling activity; none for control under pavement.

Comparative efficacy: Equally effective chemical alternatives are available.

Comparative costs: Sodium arsenite: 12 to \$40/1,000 sq. ft., herbicide 60 to \$80/1,000 sq. ft., sterilant; sodium borate-chlorate: 3.11 to \$24.90/1,000 sq. ft., herbicide 12.45 to \$24.90/1,000 sq. ft., under pavement.

Comments: None.

D. EXTENT OF USE: Not known; not widely used in the paving industry or for railroad rights-of-way.

E. ECONOMIC IMPACTS:

Users: Little, except for use under pavement.

Market: Unknown.

Macroeconomics: Small.

F. SOCIAL/COMMUNITY IMPACTS: Small.

G. LIMITATIONS OF THE ANALYSIS: Lack of data on extent of use and alternatives.

H. ANALYSTS AND DATE:

D. R. Keeney	W. A. Quinby
Soil Scientist	Agriculture Economist
University of Wisconsin	USDA
Madison, Wis.	Dec. 27, 1979

Sodium Arsenite—Subterranean Termite Control

A. USE: Used to control subterranean termites under industrial structures.

B. PEST CONTROLLED: Termites.

C. ALTERNATIVES:

Chemical alternatives: Alternatives include aldrin, dieldrin, chlordane, and heptachlor.

Nonchemical controls: None.

Comparative cost:

Not available.

Comments:

Treatment using sodium arsenite in industrial structures should be limited to locations where there is no high water table. Sodium arsenite is converted to sodium arsenate on contact with water and air. Sodium arsenate is highly soluble in water and in areas of high water table would not remain near the structure to control termites. Sodium arsenite is not recommended for residential use.

D. EXTENT OF USE:

No known use for this purpose. There may be a minimal amount used by commercial applicators.

E. ECONOMIC IMPACTS:

User:

The impacts are probably minimal as alternatives are more effective.

Consumer:

No impacts expected.

Macroeconomics:

None.

F. SOCIAL/COMMUNITY IMPACTS:

None.

G. LIMITATIONS OF THE ANALYSIS:

Estimates of industrial structural treatment costs by sodium arsenite were not available.

H. ANALYST AND DATE:

Walter L. Ferguson
ESCS, USDA
Washington, D.C.
Dec. 28, 1979

Sodium Arsenite—Grape Disease Control

A. USE:

Treatment of grapes in San Joaquin Valley of California.

B. MAJOR PESTS CONTROLLED:

Black Measles and Phomopsis cane and leaf spot.

C. ALTERNATIVES:

Major-registered chemicals:

Black Measles - no alternative. Phomopsis - primarily dinoseb. Other chemicals provide suppression of disease.

Non-chemical controls:

None.

Efficacy of alternatives:

For Phomopsis, dinoseb gives equal control.

Comparative costs:

For Phomopsis, dinoseb costs \$19.65 per acre more than sodium arsenite (82 % increase).

Conclusions:

Losses will occur on the acreage now protected from Black Measles. Effective control of Phomopsis is obtained with dinoseb at a higher cost.

D. EXTENT OF USE:

Sodium Arsenite Use	Black measles		Phomopsis
	Fresh Market Grapes	Raisins	Fresh Market Grapes and Raisins
Acres treated/ year	8,950	1,050	5,000
Percent of bearing acres	11	1	NA
Years of control/ treatment	3	6	1
Acres protected	26,850	6,300	5,000
Percent of bearing acres	34	5	NA
Pounds As_2O_3 /acre	9	6	6
Pounds As_2O_3 /year	80,550	6,300	30,000
Chemical cost	\$120,825	\$ 9,450	\$ 45,000
Application cost	\$134,250	\$15,750	\$ 75,000
Total cost	\$255,075	\$25,200	\$120,000

E. ECONOMIC IMPACTS:

User:

On the 33,150 acres affected by Black Measles, the present value (using a 7% discount rate) of production losses would increase from \$620,500 in the first year to \$1.7 million in the sixth year; the total of these losses for the first 6 years following a cancellation would be \$7.4 million.

On a per-acre basis, the annual losses would increase from an initial level of 19 to \$52 after 6 years; per-acre losses for the 6-year period would be \$223.

During the first 6 years, annual net returns would decline by 27 to 30% for fresh market grapes and 2% for raisins if farm price levels are unaffected by the production losses over time.

In addition to the production losses, Black Measles would cause vineyard bearing life to decrease by 5 to 7 years, resulting in annual establishment cost increases of \$817,650 (\$565,200 for increased investment costs and \$252,450 for foregone net income) or \$24.67 per acre.

Production Loss from Black Measles After Cancellation

Year	Tonnage Affected		Net Loss - Current Value	Net Loss - Present Value
	Fresh Market Grapes	Raisin (Fresh basis)		
<hr/>				
<div>- - 1,000 Dollars - -</div>				
1	2,037	116	664	620
3	4,075	273	1,616	1,319
6	6,111	452	2,573	1,714
Total (for 6 years)	24,477	1,702	9,709	7,405

On the 5,000 acres affected by Phomopsis, annual production costs would increase by \$98,250 or \$19.65 per acre; losses in production are not expected.

Market and Consumer:

Six years after a cancellation, California production of fresh market grapes and raisins is expected to decline by 1.67 and 0.04%, respectively. Production changes of this magnitude over a 6-year period are not expected to have measurable effects upon farm or consumer prices.

Macroeconomic:

None expected.

F. SOCIAL/COMMUNITY IMPACTS:

None expected.

G. LIMITATIONS OF THE ANALYSIS:

Loss estimates are not well supported by experimental data; losses are highly variable over time and between vineyards. Raisin losses will continue to increase beyond the 6-year analytical time frame. The analysis of increased annual investment costs due to shortened vineyard life does not reflect the difference between historical and current cost of vineyard establishment.

H. ANALYSTS AND DATE:

B. Ted Kuntz	Ralph Freund
Economist	Agricultural Economist
NRED/ESCS	EAB/BFSD/OPP/EPA
USDA	Washington, D.C.
Corvallis, Oreg.	April, 1980

CHAPTER 3: CREOSOTE, COAL TAR, AND COAL-TAR NEUTRAL OILS

	<u>Page</u>
Methods of Application.	215
Use Patterns and Efficacy	216
Herbicidal Uses	218
Fungicidal Uses	218
Insecticidal, Miticidal, Larvicidal, and Repellent Uses	218
Animal Quarters	219
Gypsy Moth Control.	220
Larvicides.	220
Repellents.	220
Animal Dip.	221
Disinfectant Uses	221
Farm and Ranch Uses	221
General Disinfectant Uses	222
Exposure Analysis	224
Fate in the Environment	227
Air	227
Water	228
Soil.	229
Plants and Animals.	230
Alternatives.	230
Herbicidal Uses	230
Fungicidal Uses	231
Insecticidal, Miticidal, Larvicidal, and Repellent Uses	231
Animal Quarters	231
Animal Dip.	233
Larvicides.	233
Gypsy Moth Control.	234
Repellent Uses.	234
Bird Repellent.	234
Animal Repellent.	235
Insect Repellent.	235
Disinfectants	236
Summary of Biological Analysis of Creosote, Coal Tar, and Neutral Oils.	237
Economic Impact Analysis of Canceling Creosote, Coal Tar, and Neutral Oil Uses.	239
Current Use Analysis.	239
Limitation of the Analysis.	239
Extent of Use	240
Summary	254
Summary of Economic Impact Analysis of Canceling Creosote, Coal Tar, and Neutral Oil	255

CHAPTER 3: CREOSOTE, COAL TAR, AND COAL-TAR NEUTRAL OILS

Certain coal-tar distillates, primarily low-boiling fractions composed principally of naphtha and methylnaphthalene and known in the trade as "neutral oils," are used for several pesticidal applications that are of a non-wood preservative nature. Both coal tar and creosote are included in formulations that also contain tar acid fractions and other ingredients, and which are intended for some of the same uses as those for neutral oils. A summary of the various uses of products containing neutral oils, creosote, and coal tar is given in Table 94.

Table 94.--Site pest information for coal tar, creosote, and neutral oils, exclusive of wood preservatives

Type Use	Method of Application	Sites	Ingredients		
			Neutral Oil	Creosote	Coal Tar
Disinfectant and deodorizer	Spray, pour, brush, mop, wipe, immerse, wet down	Animal quarters, sick rooms, bathrooms, kitchens, public buildings	X		X
Mosquito larvicide	Spray, pour	Stagnant pools of water	X		
Bird repellent	Treat seed	Seed	X	X	X
Screwworm control	Mop	Farm animals	X		
Fungicide	Saturate	Dogs		X	X
Animal repellent	Spray, pour	Lawns, flower beds, fencing		X	X
Herbicide	Spray	Nutgrass		X	
Mosquito repellent	Wipe	Human skin			X
Insecticide	Spray, pour	Sewers and drains	X	X	
Gypsy moth control	Spray	Egg clusters	X		
Miticide	Spray	Poultry houses		X	
Animal dip	Immerse, spray, brush	Non-food animals		X	X

The varying definitions assigned to the term "neutral oil" are a source of confusion. In presuming against neutral oil, the EPA (Federal Register, 1978) defined this product as a mixture of hydrocarbons of coal-tar origin from which the tar acids and tar bases have been removed. Basically, this definition covers the neutral fraction of creosote and includes all the constituents shown in Table 75. The Assessment Team was unable to verify that a product conforming to this definition is produced or used in the United States. The coal-tar distillate referred to as "neutral oil" and used for the various types of applications referred to above is composed of 75% methylnaphthalenes and 25% coal-tar naphtha. It does not contain the high-boiling fractions encompassed in EPA's definition and for which there is some evidence of carcinogenicity in animals. This document addresses only that product that is currently being produced and used.

Although pesticides of coal-tar origin have been used for well over 100 years, literature on these products is quite limited. In particular, the Assessment Team was unable to find data on quantities of neutral oils, coal tar, and creosote that are produced for non-wood preserving purposes, methods of applications, and exposure at the point of manufacture and at the point of end use. This information gap was filled in part by direct contact with the producers and, to a lesser extent, the users of coal-tar-based pesticides. All producers of record were contacted both by telephone and by mail questionnaire. Approximately 20% of these firms were recontacted by telephone. In addition, several major retail outlets were contacted by telephone and by letter. The purpose of these contacts was to obtain information on methods of formulation, employee exposure, the quantities sold by type of use, to whom the products were sold, and other points of a related nature.

These contacts were less productive than was desired because the companies involved appeared to have little information on the chemical composition of the raw materials that they use in formulating their products, lack data on employee exposure, and were able to provide essentially no information on who uses their products, in what quantities, or for what purposes. It follows that the data base to which this report is anchored is considerably less than satisfactory. The confidence that can be placed in the various statistics used throughout the report is indicated by expressions of the number of plants or percentage of the industry upon which the statistics are based.

Methods of Application

The various methods of application of pesticides containing neutral oils, creosote, and coal tar are listed in abbreviated form in Table 94. The method of application used depends upon the purpose (disinfectant, larvicide, etc.) and the application site.

When used as a disinfectant, the diluted product may be sprayed on the surface of concern using a garden-type sprayer, or, in the case of floors, applied with a mop. Items of equipment may be sterilized by simply wiping with a cloth, brushing, or mopping. Complete immersion is recommended for small items of equipment.

Wet down, sprinkle, spray, wipe, mop, scrub, immerse, sponge, and brush are all mentioned by one or more manufacturers as acceptable methods of applying these products for purposes of disinfecting premises or equipment. They are recommended for use in animal shelters, animal feeding and watering equipment, households, institutional buildings, and transportation equipment as both a disinfectant and deodorant. In 1970 the USDA canceled the registrations of products containing coal tar neutral

oil-coal tar acid combinations for use in dairy barns and the registration of products containing creosote for use in food-animal quarters; however, products containing neutral oil are still permitted and apparently are widely used in applications of the latter type.

Methods of application recommended for coal-tar products as a miticide, insecticide, etc., vary, as above, with the particular pest and site combination. When coal-tar products are used as a miticide in poultry houses for control of chicken red mites, the entire area--walls, floor, and ceiling--may be sprayed. Such applications are normally routinely scheduled for interim periods between the time the birds in a house are marketed and a new population is quartered in the area. The use of products containing neutral oil in poultry houses was canceled by EPA in 1971, but the use of creosote is permitted.

Control of mosquito larvae typically involves simply pouring the product into water that serves as a breeding place for this insect. Applications are normally made in undiluted form and dosage is regulated in terms of the volume of water involved. Control of animal parasites such as fleas, ticks, and lice usually involves spraying or sprinkling the diluted product over the subject, or, if it is a small animal such as a dog, simply immersing it. The use of neutral oils and other coal-tar distillates for this purpose is restricted by USDA regulations to non-food animals.

Creosote and coal tar, either alone or in combination with various other products, are sold as repellents. These formulations are used on seed to prevent or discourage their ingestion by pheasants, crows, blackbirds, and starlings. For this particular use, the seeds are simply treated with the product prior to sowing. The total production of coal-tar products of at least one company is used for this purpose. Other repellent applications include soaking a specially designed sorptive material mounted on a stick and placing it in flower beds or other similar locations to discourage the use of the area by dogs. Then, too, creosote is commonly applied to stalls and fencing by brush or spray to discourage cribbing by horses. Finally, coal tar is formulated with camphor, oil of citronella, and methyl salicylate and used as an insect repellent against gnats, mosquitoes, and deer flies. This latter use requires that the product be applied directly to the skin.

Neutral-oil-containing formulations are also recommended for such additional uses as control of maggots and drain flies in drains, septic tanks, toilet facilities, and garbage trucks. Spray and pour applications, as appropriate, are used. They may also be used to kill screwworms in animals, by inserting a cotton swab coated with the product into the infected area and mopping it onto the grub, and as a fungicide in the control of ringworms.

There is a single registration for the use of creosote in diluted form as a herbicide in the control of nutgrass in flower gardens and lawns. A foliar spray is used to apply the creosote.

Use Patterns and Efficacy

Approximately 330,000 gallons of various formulations containing neutral oils are produced annually. This estimate is based in part on sample survey returns from 25% of the firms holding registrations for pesticides containing neutral oils, and in part on discussions with selected producers of coal-tar distillates. No reliable data are available on the percentage of total production that goes to the various uses of these products--that is, disinfectants, fungicides, larvicides, etc.; however, limited information gleaned from industry responses to a mail survey, as well

as telephone interviews with managers of farm cooperatives, strongly suggests that most of the production goes for farm and ranch uses and that disinfectant uses are the most important, probably accounting for well over 50% of production.

A relatively small percentage of neutral-oil products is sold directly by the manufacturer to the ultimate consumer. The greater part of production--an estimated 95%--is sold to farm cooperatives, farm supply stores, veterinary supply stores, pharmaceutical supply companies, and other distributors, as well as to jobbers. Some producers sell bulk quantities of their products to repackaging firms.

Although only 330,000 gallons of pesticides containing neutral oils are produced annually, the volume of ready-to-use solution is substantially greater because of the high dilution ratios employed. Based on label data for approximately 75% of the brand-name products currently marketed, these dilution ratios range from a low of 32:1 to a high of 350:1 for most uses, exclusive of those for which the product is applied in undiluted form.

The dilutant recommended is water. The average dilution ratio, considering all uses, is about 60:1. This ratio includes products that are recommended for use in undiluted form. If they are excluded, the average ratio is about 89:1. If one uses the smaller ratio and assumes that the ratios are nominally distributed, it is evident that approximately 20 million gallons of ready-to-use solution are applied annually.

Neutral oil concentrations in the products as formulated average 48.7% and range from 2.6 to 63% for uses exclusive of wood preservatives. If a dilution ratio of 89:1 is assumed for all except preservative uses, the average concentration of neutral oils in ready-to-use solutions is about 0.5%. Formulations sold for use as wood preservatives have neutral oil contents of 90% or higher and are applied full strength.

Projections of future demand for coal-tar-based disinfectants cannot reliably be made because of the inadequacy of the data base. Respondents to the mail questionnaire varied little, however, in their estimates of future sales. Most expressed the belief that sales would remain essentially steady for the foreseeable future. A few of the respondents expressed the contrary view that sales would increase slightly because of cancellation of some of the "modern" pesticides.

The question arises as to why these products are used when, for many of the applications for which they are intended, there are numerous substitute pesticides for which efficacy data show a high level of effectiveness. The reason is due, in part at least, to custom and tradition. The products have been in use for over a century, and during much of that period were the only products available. Their employment for many purposes has been recommended for years by the USDA and by State agricultural extension and research authorities. Then, too, many people associate the characteristic odor of these products with cleanliness and aseptic conditions. Also, cost is undoubtedly a factor, as coal-tar-based pesticides are less expensive for many--if not most--applications than potential substitutes. The cost per gallon as applied is about 11 cents. Finally, effectiveness must be considered, and the available data suggest that these products are generally more efficacious as disinfectants than many of the common alternative chemicals because they remain active for longer periods of time in the presence of organic materials.

Data simply do not exist on the quantity of coal-tar-based pesticides used in various applications. One can, however, perceive the relative importance of these

applications from the number of site/pest combinations for which registrations are on file.

Herbicidal Uses

A single registration exists for the use of a coal-tar distillate--in this case, creosote--as a herbicide. The creosote is blended with petroleum distillates and applied directly as a foliar spray in the control of nutgrass. Two sites are listed: flower gardens and ornamental lawns.

Creosote and creosote coal-tar solutions have also been used extensively in the past by the wood-preserving industry for the control of weeds and grass on product storage yards. This use has been one of convenience rather than necessity, because of the availability of creosote oil which, because of contamination or other reasons, was unsuitable as a preservative. Pollution-control regulations applicable to this industry have severely curtailed this use.

Herbicidal uses of coal-tar products outside of the wood preserving industry are currently limited, if indeed they are practiced at all. Turfgrass experts and weed scientists, as well as USDA personnel, are not aware of any use of these products for that purpose. Efficacy data are lacking, but it was generally agreed that coal-tar products are poor substitutes for several alternative herbicides now available.

Fungicidal Uses

Although coal tar, creosote, and neutral oils find wide application as a fungicide in the control of decay and other wood-inhabiting fungi, their uses outside this substrate are limited. Review of label data revealed only one such registration, and it was for control of ringworm on horses. No evidence was uncovered to indicate that neutral-oil products are, in fact, still used for this purpose. Efficacy data are not available.

Creosote and coal tar are registered for use as a fungicide to protect cordage and canvas from fungal infection, and also to provide some level of resistance to water penetration. The extent to which they are used for this purpose is unknown.

Insecticidal, Miticidal, Larvicidal, and Repellent Uses

Coal-tar distillates are used to a limited extent in the control of insects associated with livestock and animal--including human--waste products. For most uses, control is achieved by killing the pest. An exception is their use as repellents for insects and birds, as well as animals. The relative importance of those coal-tar products of concern here can be obtained from the following tabulation, which shows the number of registrations for creosote, coal tar, and neutral oils by types of uses.

<u>Use</u>	<u>Neutral Oil</u>	<u>Creosote</u>	<u>Coal Tar</u>
Repellent			
Bird		1	1
Insects			1
Animals		2	
Insecticide			
Gypsy moth	2	1	
Drain flies	1		
Flies (unspecified)	1		
Animal parasites ^a	21	1	1
Ants	1		
Larvacide			
Mosquitoes	16		
Maggots	2		
Miticide			
Chicken mites	6	1	

^a Includes lice, ticks, fleas, and screwworms; does not include mites.

It is apparent that neutral oils are the most important of the three coal-tar distillates, the use of creosote and coal tar being confined mainly to repellent uses, based on available data. The extent to which these products are actually used for the purposes noted is unknown; however, the responses to the aforementioned mail questionnaire supply some insight into this question. Based on these data, which are at best inadequate, 19% of the production of formulations containing neutral oils is used in whole or in part as an insecticide, miticide, or larvicide. This percentage would indicate that approximately 62,000 gallons of concentrate are devoted to this purpose annually.

Animal Quarters

Coal-tar products are apparently used extensively in the control of such animal parasites as lice, ticks, fleas, screwworms, and mites in animal quarters. Registrations of these products for use on food animals have been canceled, but they continue to be used in animal quarters and on nonfood animals such as dogs and horses.

Products containing neutral oils were formerly used extensively for the control of mites in poultry houses, but registrations for this use were withdrawn in 1971. This fact notwithstanding, some labels for neutral-oil products still list this use and indications that they are, in fact, being used for this purpose were obtained in conversations with both the producers of neutral-oil products and managers of farm stores. Creosote is still officially registered (1 label) for control of mites in poultry houses.

Efficacy data on coal-tar products for the types of uses outlined above were not available to the Assessment Team.

Gypsy Moth Control

The use of neutral-oil-containing products and creosote is a regulatory treatment in the control of the gypsy moth by the USDA Plant Protection and Quarantine Program (Wood, 1979). Specifically, these products are used to treat egg masses of the gypsy moth that are located during inspection of products being shipped out of quarantine areas. When located on forest products, vehicles, or other objects or products, the egg masses are simply coated with the coal-tar distillate in undiluted form.

A relatively small amount of neutral-oil product (under 100 gallons/year) is utilized in this control program. Its continued use is considered essential by USDA because, when used selectively, it may prevent great economic destruction by the gypsy moth in presently non-infested areas. This will also prevent subsequent use of large amounts of insecticides in the future. The insect is capable of causing extensive damage to both hardwood and coniferous forests, as well as to shrubs and other plants used for landscaping purposes. Tests are continuing, but no promising materials have been found to date that will serve this need.

Larvicides

Neutral oil coal-tar acids are registered for use in the control of mosquito and fly larvae and screwworms in horses and mules.

The use of these products for mosquito control involves the spraying or pouring of the insecticide onto the surface of stagnant waters in amounts designed to cover the water surface with a thin film. Effective substitute materials are available for this use, and the available information indicates that the current usage of neutral-oil products in mosquito-control programs is quite limited (McWhorter, 1979).

Treatment of screwworms in horses and mules is likewise believed to be an extremely minor use of coal-tar products. No information was uncovered by the Assessment Team to confirm that these products are used at all for this purpose.

Neutral-oil products are used for the control of maggots and flies in garbage trucks, where its application serves doubly as a disinfectant. The importance of this use, the amount of product consumed for this purpose, and the efficacy of the treatment are unknown; however, neutral-oil products are used for the control of drain flies and their maggots in drain lines, toilets, and similar locations. The continued availability of these products for this purpose is believed to be important, because no alternative chemicals have been registered.

Repellents

Creosote, coal tar, and neutral oils are used either alone or in combination with other products as animal and bird repellents. Coal tar is, in addition, registered for use as an insect repellent in preparations intended for use on human skin.

The use of these products as animal repellents is limited in terms of the quantity involved, and it could not be verified that they are in fact used for all the repellent purposes for which they are registered. They are apparently used to some extent in lawns and flower beds to discourage the use of these areas by dogs. In addition, creosote is commonly brushed or sprayed in stalls and on wooden fences to prevent cribbing by horses. This latter use is apparently widely practiced and considered to be important by people who own or work with horses (Alford, 1979). No

alternative materials for this purpose seem to be available, except other coal-tar distillates.

Fairly extensive use was made in the past of coal-tar products in the treatment of seed, particularly corn, to prevent or discourage their ingestion by birds. Creosote and neutral oils are still used for this purpose either alone or in combination with other products, such as turpentine. The Assessment Team was able to locate only one company that formulates and sells a bird repellent based on coal-tar distillates (see Repellent Uses in this chapter).

Animal Dip

Coal-tar distillates, including coal tar itself, have been used for a century or more for the control of parasites such as ticks and mites, on animals. Current restrictions on these products limit their use to dogs and other non-food animals. Large animals such as horses are simply wet down with a water emulsion formulation. Small animals may be immersed, sprayed, or bathed in the material.

There are approximately 10 registrations for animal-dip formulations based on neutral oil-coal tar acid combinations (8), creosote (1), and coal tar (1). These products are used extensively for this purpose and are reported to be quite effective (Hidalgo, 1979).

Disinfectant Uses

The use of coal-tar distillates as a disinfectant is the single most important non-preservative use and accounts for an estimated 50 to 80% of total production of those formulations containing neutral oils. The well-established customer acceptance of these products as disinfectants is probably due to a combination of their effectiveness, economic consideration, aesthetic factors, and their availability over a period of many years.

If it is assumed that 65% of the total volume of coal-tar-based pesticides that contain neutral oils as an ingredient is used as disinfectants, the quantity involved would be about 215,000 gallons of concentrate, or about 13 million gallons of ready-to-use solution. This estimate is based on a concentrate production of 330,000 gallons per year and a dilution ratio of 60:1. It is assumed that most of this material is used to disinfect animal quarters and equipment that are associated with farm and ranch work; however, neutral-oil formulations are registered for residential and institutional uses as well.

There are currently 406 separate site/pest registered uses of coal-tar distillates as disinfectants that contain neutral oils or coal tar. Only 13 of these contain coal tar; none contains creosote.

Farm and Ranch Uses

The efficacy of coal-tar distillates for farm and ranch use results from two facts: 1) they are quite effective against animal bacteria, including Pseudomonas; and 2) they retain their effectiveness for long periods of time in the presence of organic matter (Gaskin, 1974). This latter point is particularly relevant as it applies to agricultural uses. Many chemicals which, in other applications, may be viable substitutes for those of coal-tar origin generally have very poor activity and little residual effect in the presence of the organic matter that is an inevitable part of livestock operations. Thus, for example, chlorine in the various forms available for use as disinfectants has a wide germicidal range, but it has poor

activity in the presence of organic matter. Likewise, quaternary ammonium compounds, which ordinarily have fair to good germicidal activity in the absence of organic material, as well as iodine, are generally ineffective in its presence. Even after thorough cleaning, preparatory to disinfecting, the organic matter remaining, even in minute amounts, is more than enough to inactivate organic-sensitive disinfectants.

Products containing neutral oil-coal-tar acid combinations are used extensively as general disinfectants in livestock quarters, exclusive of dairy parlors, but including cattle pens, pig sties, sheep folds, farrowing houses, barns and other shelters, and poultry houses.¹⁷ They are also used as a disinfectant for feeding and watering equipment, vehicles used to transport livestock, halters, ropes, and for other general disinfecting uses associated with animal production.

Coal-tar-based disinfectants containing 50% or more cresylic acid and 21% or more soap are "permitted disinfectants," which, upon specific approval by USDA Veterinary Services, may be designated for use in the control of virulent animal diseases such as tuberculosis, anthrax, European fowl pests, etc. (Anonymous, 1971, 1978, and 1978a). Specifications for these products (Anonymous, 1978) are such that the formulations cannot contain neutral oils. Specifically, these products must be soluble in water, a requirement that disinfectants containing neutral oil cannot meet.

Personnel in the USDA (Miller and Mackery, 1979) indicate that the use of coal-tar-based disinfectants is a significant part of the animal disease control program at the farm and ranch level in the United States. The products are simple to use, inexpensive, and have been shown to be effective as general-use disinfectants.

General Disinfectant Uses

Although most disinfectants containing neutral oils are used in farm and ranch applications, many of these products are also registered as a disinfectant for home and institutional use. The quantity actually purchased for this purpose is unknown, but telephone calls to randomly selected producers verified that part of their production finds use in non-agricultural applications. Specifically, it is used as a disinfectant in outhouses and other sanitary facilities at parks, camping grounds, highway rest stops, and other public facilities. It is also used as a disinfectant-deodorant for garbage cans, garbage trucks, and related equipment.

The extensive use in home and institutions of the proprietary disinfectant, Lysol[®], which for many years was based on coal-tar distillates, strongly suggests that the related products of concern here are also currently used to some extent as a general household disinfectant. Suggested uses on labels indicate that they are used in bathrooms, sick rooms, and as an all-purpose disinfectant for floors, walls, and kitchen sinks, among other sites.

The availability of test data on disinfectant formulations containing neutral oils that were obtained by following the procedures of the Official Methods of Analysis of the AOAC are limited (Kiggins, 1979). Data which were made available to the Assessment Team show a high degree of effectiveness against the bacteria used. One set of such data obtained in tests conducted by Hill Top Research, Inc.,

¹⁷Cancellation in 1971 of the registrations of these products for use in poultry houses has not prevented their continued use for this purpose.

Miamiville, Ohio, is shown in Table 95 for a typical formulation containing the following ingredients in the percentages indicated:

Coal tar phenols	14.0%
Neutral coal tar oils	61.6%
Anhydrous soap	14.4%
Water	10.0%

The data in this table show that the disinfectant tested had a critical killing dilution of 1:509. A duplicate test conducted on the same organism 6 weeks before the one reported showed a critical killing dilution of 1:535.

Table 95.--Evaluation of growth of Salmonella typhosa after treatment with various dilutions of a coal-tar-based disinfectant; phenol coefficient: 6.4

Dilution	Exposure Time (min.)		
	5	10	15
1:382	-	-	-
1:421	-	-	-
1:463	-	-	-
1:509 ^a	+	-	-
1:560	+	+	+
1:616	+	+	+
1:678	+	+	+
1:746	+	+	+
1:895	+	+	+

^a Critical killing dilution: 1:509

Other tests conducted by the Wisconsin Alumni Research Foundation (WARF) Institute, Inc., Madison, Wis., for a producer of disinfectants containing neutral oil are summarized in Table 96 (Kiggins, 1979). The purpose of these tests, each group of which was conducted in culture lots of 10 to 20 over a period of time, was to ascertain the effect of shelf residency on efficacy. A 1:48 dilution was used in all tests. The test organism was Salmonella choleraesuis. Only one positive reading was obtained in the 480 culture tubes included in the study.

Table 96.--Results of AOAC use dilution test of a coal-tar-type disinfectant against Salmonella choleraesuis

Lot Number	Number of Culture Tubes		Growth Results	
	Primary	Subculture	Primary	Subculture
1	60	60	59	59
2	60	60	60	60
3	60	60	60	60
4	60	60	60	60

Exposure Analysis

Opportunity for exposure to neutral oils--either by skin contact or inhalation--during manufacturing and packaging varies with work position within the plant. Undoubtedly, it also varies among plants. Most of the companies that formulate and/or package neutral oil products are either quite small, having relatively few employees, or, as in some cases, neutral oils are only a very small part of a complex product line of chemicals and pharmaceuticals. Production among companies surveyed ranged from 175 to 100,000 gallons per year and averaged 19,500 gallons. Many companies produce less than 500 gallons per year.

The product used in the formulation of neutral-oil products is tar acid oil, a blend consisting of approximately 20% acid fraction, 60% mono- and dimethylnaphthalene, and 20% coal tar naphtha. The two latter components are known collectively in the trade as crystal-free neutral oil. The acid fraction is a mixture of phenols, cresols, xylenols, and trimethylphenols, which collectively are known as cresylic acid.

Upon receipt of a shipment, which may arrive by rail tank car or truck, a second sample is collected by the receiving clerk and transferred to the quality control laboratory for testing. Upon approval of the shipment, the tar acid oil is transferred by a closed system from the rail car or truck to a steel storage tank, the capacity of which is determined by the plant's production. Ventilation equipment located adjacent to the entry port of the storage tank exhausts displaced air from the tank to the outside. Upon completion of unloading, one employee disconnects and removes the flexible, stainless hose used in the transfer operation. It is assumed--and some companies have stated--that this hose is dedicated to that use only. At some plants, the tank is equipped with a measuring device to facilitate inventory control and is also useful in preventing overflow.

During formulation, the tar acid oil is pumped from the storage tank to working tanks from which the liquid is drawn as required. The pump employed during this transfer is flushed with water after every use and the waste thus created is collected for appropriate disposal. All plumbing used in the operation is dedicated to this use. The working tanks are constructed of steel, are equipped with covers to control vapors, and are calibrated to measure batch quantities. One employee is involved in the transfer of the tar acid oil from the storage tank to the working tanks, and thence to mixing tanks. The room in which this equipment is located is usually equipped with an exhaust fan leading to the outside.

The mixing tanks in which the actual formulating operations take place are constructed of steel and are equipped with steam jackets and a cover. All major ingredients are charged through pipes leading into the mixing tanks through the cover. Large exhaust fans are used to minimize the concentration of vapors in the formulating room. The actual formulating operation, which is handled by one employee, proceeds as follows:

1. Pump tar acid oil to working tanks.
2. Add fatty acid to mixing tank from barrels in which it was received.
3. Discharge a quantity of tar acid oil to the mixing tank. The amount added at this point varies with the size of the batch of final product being prepared.
4. Start mixer and heat to 176° F.

5. Slowly add antifoam agent and 30% sodium hydroxide, the latter coming from steel drums as received.
6. Maintain temperature between 176° F and 190° F for 1-1/2 hours.
7. Add the balance of the tar acid oil.
8. Add deionized water.
9. Mix for 30 minutes while maintaining temperature at 190° F or less.
10. Stop the mixer, obtain a sample of the product, and test.

A typical product produced by the above operation has the following approximate composition.

Coal tar phenols	14.0%
Neutral oils	61.6%
Anhydrous soap	14.4%
Inert ingredients (water)	10.0%

This material may be stored in the mixing tanks until it is packaged, or it may be pumped to bulk storage tanks.

Packaging of the product is performed by using a filling machine of stainless steel construction with tygon tubing connections. In the better-managed plants, this machine is equipped with a hood connected to an exhaust fan which draws air away from the operator past the filling heads and over the filter reservoir. The fan is operated continuously while the equipment is in use. Several packages are filled simultaneously and capped immediately. One person operates the machine, but other employees are present to supply empty containers and remove filled ones. The product is shipped in metal cans (gallon, quart, or pint) packaged 6 or 12 to a carton.

Employee exposure at the point of manufacture is a function of the sanitation practices enforced, the location and efficiency of engineered ventilation equipment installed, availability and use of safety equipment, and the number of batches of product prepared annually. Responses to a mail questionnaire suggest that at least minimal standards of safety and sanitation are maintained within the industry. Eighty-eight percent of the respondents stated that safety equipment is made available to employees, and all except one firm indicated that the use of this equipment is required. Representatives of OSHA have inspected 67% of the plants, and all plants responding indicated that they meet applicable standards with regard to ventilation and other employee safety standards.

Total employee exposure is probably quite small, if for no other reason than the small number of batches of product formulated and packaged annually. The average number of batches per company per year is 8 and varies between 2 and 10. This statistic does not provide a complete picture of employee exposure because some firms operate two mixers and thus are capable of preparing more than one batch at a time. A more definitive estimate of exposure is provided by the number of days that formulating and packaging operations take place. In this regard, the following data, which were supplied by a single company with an approximately average annual production, may provide a more reasonable estimate of exposure:

Year	Days	
	Formulating	Packaging
1974	12	-
1975	11	-
1976	18	-
1977	10	12
1978	10	11

The numbers of employees, by job description, who would receive some level of exposure on the days that formulating and packaging take place are summarized in Table 97. The total number of people in the industry that have direct contact with neutral-oil products--either dermally or by inhalation--is estimated not to exceed 1,000.

Table 97.--Summary of exposure to neutral oil products at point of manufacture

Number of Employees	Job Description	Hours of Exposure Per Year	Intensity of Potential Exposure ^a	
			Skin Contact	Inhalation
1	Receiving clerk	2	5	5
1	Liquids supervisors	48	5	4
1	Liquids compounder	80	5	4
4	Liquids packager	96	5	5
2	Laboratory personnel	96	5	4

^a 1 = consistent high exposure; 2 = occasional high exposure; 3 = consistent moderate exposure; 4 = occasional moderate exposure; 5 = minimal exposure.

An assessment of exposure to neutral-oil products at the point of end use is difficult because of the many and varied uses of these products and the fact that information is lacking on the quantity that is sold for each major use. Likewise, there is a dearth of information on the frequency of use for any given site/pest combination, as well as on the methods of application employed. Exposure is probably more a function of method of application than it is the purpose of the application. Thus, for example, the exposure potential for applications that involve spraying or mopping is probably greater than it is for those that involve simple pouring. Severity of exposure even for the former application method is mitigated somewhat by the fact that the product has a neutral-oil content of only about 0.5% after dilution.

Well over 80% of the neutral-oil-containing products are used for disinfectant and insecticidal purposes and are applied by spraying. Undoubtedly, the greater part of the material sold for these purposes is used in livestock quarters, although some finds use in households and institutional buildings. There is a potential for occasionally high to occasionally moderate exposure by both inhalation and dermal contact, the exact severity depending upon the use of protective clothing and equipment, including respirators. Total annual exposure would depend upon frequency of applications, which is unlikely to exceed 4 hours per day, 3 to 4 days per year for most

farm and ranch uses. This estimate presupposes that applications are made in the interim between marketing of livestock, such as hogs and chickens, and moving a second population into a shelter.

The level of exposure from applications in households and institutional facilities may very well equal in total that for farm and ranch use because of greater frequency of use. Exposure resulting from the mop-and-wipe-type applications that characterize disinfecting operations in bathrooms, sick rooms, and in public buildings may range from occasionally moderate to consistently high depending upon whether the application is conducted on a weekly schedule in a household or is a full-time job for custodial personnel in public buildings.

Exposure from such other types of applications as disinfecting farm feed and watering equipment and dipping small animals also has the potential of ranging from occasionally high to minimal, depending upon the frequency of such applications and whether protective clothing is used. Quarantine use for gypsy moth control involves brushing the material on the egg mass; thus little dermal contact is likely and inhalation exposure is minimal.

The total number of people in the neutral-oil user group is probably high relative to that of the producer group, and may range up to 100,000 to 500,000. The chronic health hazard involved is unknown, but is assumed to be small, because the neutral oil used by the industry is composed of mono- and dimethylnaphthalenes and coal tar naphtha only. It apparently does not contain any of the high-boiling polynuclear aromatic hydrocarbons, such as benzo-a-pyrene, chrysene, etc., which were reputed by EPA in its Position Document to be in this product and to be carcinogenic.

Acute health hazards involved in the use of neutral-oil products are apparently quite small. Among respondents to a question inquiring about health-related complaints received by manufacturers of neutral-oil products, only one such instance was reported and it involved superficial skin irritation by a user. This is a good record, considering that the respondents to this question represented approximately 20% of the industry and that many of the companies have been manufacturing products containing neutral oils for 25 to over 100 years.

Fate in the Environment

The fate in the environment of the components of neutral oil, primarily mono- and dimethylnaphthalene, is not well documented in the literature. A summary of those references which relate to this subject is presented here.

Air

Because methylnaphthalenes are low-boiling fractions of creosote (240°-244° C) and, in addition, because there is an inverse relationship between distillation temperature and losses in service through vaporization (Stasse, 1964), it is reasonable to assume that methylnaphthalenes enter the environment in vapor form as a pollutant. Definitive data on the quantities of these components that become airborne are limited, but measurements made by Koppers Company are revealing in this regard (AWPI, 1979). These data show that the concentrations of methylnaphthalenes generally ranged below 0.1 mg/m³ for all plant workers monitored. Area monitors located near the dehydrator and the retort door gave values of about 0.8 to 2.3 mg/m³.

Compared with the results obtained using area monitoring equipment at the Koppers Company plant, relatively smaller quantities of naphthalenes should become airborne at the ambient temperature conditions under which neutral-oil formulations

are used. There is, for example, a 30-fold reduction in vapor pressure of these compounds as the temperature is reduced from 200° to 77° F. The concentration entering the air would, of course, vary with method of application, and may actually be quite high when spraying is used.

The ultimate fate of airborne naphthalene compounds is unknown. It is assumed, however, that they are broken down in part by photochemical degradation and in part by soil microorganisms upon settling to the earth. Evidence that these compounds are subject to photochemical and microbial breakdown has been supplied by several studies (Lee, et al., 1978; Walker and Colwell, 1976; and Colwell, 1977). In fact, the naphthalenes are apparently oxidized rapidly by microorganisms (Lee, et al., 1978; Dean-Raymond and Bartha, 1975; Drisko and O'Neill, 1966; and Hepner, 1977).

The fate of creosote in quarantine use is unknown; however, the small amounts used would indicate little adverse effect. The products treated are further processed prior to direct contact with the user, and only spot treatments are applied.

Water

Naphthalene and its derivatives appear to be readily degraded in a marine environment. Thus, for example, six strains of bacteria isolated from oil-polluted water by Dean-Raymond and Bartha (1975) were all capable of utilizing naphthalene, 2-methylnaphthalene, and 2-ethylnaphthalene as sole carbon sources. Two of the six metabolized 1,5-dimethylnaphthalene and one metabolized 1-methylnaphthalene. Likewise, Drisko and O'Neill (1966) found that the mixture of organisms that colonized creosoted piling in the Port Hueneme, California, harbor metabolized naphthalene to a significant extent. In particular, Pseudomonas creosotensis was found to be very tolerant of the neutral fractions of creosote and to utilize them as sole carbon sources (O'Neill, et al., 1961). More recently, Belas, et al. (1979) found that newly installed marine piling in Puerto Rico that had been treated with a special naphthalene-enriched creosote was colonized by Hyphomicrobium vulgare within 4 days and by several other strains of bacteria within a few weeks. They reported that subsequent tests revealed that at least half of the Hyphomicrobium strains isolated from the piling were capable of utilizing naphthalene as a sole carbon source.

Reports of microbial assimilation of hydrocarbons such as those referenced above are not uncommon. Zobell, et al. (1943) observed the oxidation of naphthalene and other products of coal origin by marine organisms. Similarly, Gray and Thornton (1928) described several species of Pseudomonas that have the ability to utilize naphthalene.

The biodegradation of naphthalene, creosote, and naphthalene-enriched creosote applied to wood piling was studied by Colwell (1977). He reported that naphthalene-degrading bacteria colonized new wood piling within hours when they were installed in the coastal waters of Puerto Rico. Similarly, Traxler (1973) isolated 15 different genera of hydrocarbon-utilizing bacteria from low-temperature waters and sediments. All of the isolates metabolized naphthalenic and aliphatic hydrocarbons.

In studies conducted by Lee and Anderson (1977), it was observed that concentrations of naphthalenes added to a 1/4-scale CEPEX enclosure declined by 50% within 24 hours, and gradually declined to background levels over a period of 20 days. Reductions were attributed by the authors to adsorption by sinking phytoplankton and microbial degradation.

Different paraffinic and aromatic ^{14}C -labeled hydrocarbons added to estuarine and off-shore water samples were monitored for $^{14}\text{CO}_2$ production after incubation periods of 6 to 96 hours by Lee and Ryan (1976). Naphthalene had high degradation rates relative to higher-molecular-weight hydrocarbons. Rate of degradation was reported to be affected by season, tide, total hydrocarbon concentration, and incubation time.

Zobell, *et al.* (1943) noted that, as a rule, hydrocarbons having a boiling point above 150°C are assimilated more readily by bacteria than those having a lower boiling point. They reiterated what others have reported, namely, that bacteria found in a marine environment are capable of utilizing a wide variety of hydrocarbons, including anthracene and naphthalene. All samples of sediment which they examined contained hydrocarbon-oxidizing bacteria, regardless of distance from land, water depth, or core depth.

Soil

Soil has long been recognized as a rich source of organisms capable of metabolizing polycyclic hydrocarbons. Thus, for example, Tausson (1929) found a great variety of microorganisms in soil that utilize naphthalene and other chemicals, including phenanthrene. Likewise, Matthews (1924), in studying soil sterilization, observed an increase in total bacterial counts on soil treated with naphthalene. Her work was continued by Gray and Thornton (1928), who isolated various organisms capable of decomposing aromatic compounds such as naphthalene, cresol, and phenol. They reported on 14 bacteria that were capable of utilizing naphthalene. More recently, Kiyohara, *et al.* (1976) reported on an isolate of *Aeromonas* sp. from soil that was capable of metabolizing both naphthalene and phenanthrene.

Zobell (1950), in a review of the assimilation of hydrocarbons by microorganisms, reported that soil bacteria are capable of destroying many compounds at a rate of 0.4 to $1.2\text{ g/m}^2/\text{day}$. Naphthalene was oxidized to the extent of $3.37\text{ g/m}^2/\text{day}$. He cited numerous references which supported his view that the rapid disappearance of hydrocarbons from surface soil is a direct result of microbial activity. In concert with Matthews (1924), he reported that naphthalene promotes the growth of certain organisms when added to soil. This was further substantiated by the work of Jacobs (1931), who reported that the addition of 1.28 g of naphthalene to 100 g of soil resulted in an increase of the bacterial population from an initial count of a few million per gram to over three billion per gram. Similarly, Tattersfield (1927) noted that whereas about 50 days were required for the disappearance of 50 mg of naphthalene from 100 g of soil initially treated, the second addition of the chemical disappeared in 20 days, and the third in 10 days.

According to Tausson (as cited by Zobell, *et al.*, 1943), naphthalene, anthracene, and phenanthrene are readily utilized by many soil bacteria. Zobell, *et al.* (1943) expressed the view that, while the mechanism by which hydrocarbons are attacked by microorganisms is not fully understood, it is generally agreed that carbon dioxide and cell substance are the principal metabolites produced. Organic acids, ketones, alcohols, and other chemicals have also been detected as intermediate or end products.

Soil bacteria were found by Strawinsky and Stone (1940) to attack naphthalene and methylnaphthalene.

Plants and Animals

Only limited data are reported in the literature on the incidence of naphthalenes in animals. No data were uncovered on the occurrence of these compounds in plants.

Lee, et al. (1976) exposed blue crabs to food and water containing ^{14}C -labeled paraffinic and aromatic hydrocarbons, including naphthalene and methylnaphthalene. Two to ten percent of the labeled hydrocarbons contained in food ingested by the crabs were assimilated, and the remainder was excreted. Over 50% of the radioactivity associated with the assimilated portion was located in the hepatopancreas, and after 25 days this was the only site containing radioactivity. No evidence was found of storage of hydrocarbons in any of the crab tissue.

In other work by Lee (1975), it was observed that zooplankton took up petroleum hydrocarbons linearly for 24 hours, with no further increase after that time period. Most ingested hydrocarbons were metabolized and discharged, but about 1% was stored by all species.

Also working with zooplankton, Corner, et al. (1976) reported that the rate at which Calanus helgolandicus utilized ^{14}C -labeled naphthalene varied widely depending upon whether the chemical was accumulated directly from solution in sea water or taken up by way of food. In the former case, depuration was rapid, with less than 5% of the radioactivity taken in remaining after 10 days. By contrast, about a third remained at the end of 10 days when the hydrocarbon was ingested with food. That released by the organism was in some form other than naphthalene, thus supporting the findings of Lee (1975) that the chemical is metabolized by certain zooplankton.

Data on the utilization of aromatic hydrocarbons by higher forms of animal life are meager. Zobell (1950), however, cited several works, the results of which suggest that rats, mice, rabbits, dogs, and sheep are able to oxidize a large variety of such chemicals as part of a detoxication mechanism.

Alternatives

Herbicidal Uses

Each of the two coal-tar products registered for use as herbicides is composed of 75% percent creosote oil and 25% petroleum hydrocarbon. The Assessment Team was unable to verify that this product is used as a herbicide, as products manufactured under this registration are also sold for other purposes. Weed specialists contacted concerning this matter were not aware of the use of creosote as a herbicide, but acknowledged that it would serve this purpose if applied at a sufficiently high rate (Coates, 1979).

Unlike certain other herbicides on the market, creosote functions as a nonselective herbicide. In other words, it would be used for its knockdown ability. Common herbicides that have the same type of nonselective effect when applied as foliar sprays, and which may reasonably be considered as substitutes for creosote, are as follows:

Paraquat - under RPAR review
Roundup®
Cacodylic acid - under RPAR review
Mineral spirits
Dinoseb®
Diquat dibromide
Pentachlorophenol - under RPAR

Other herbicides that may be substituted for creosote for certain applications include 2,4,5-T, 2,4-D, and ammonium sulfamate, all of which are selective in their effect on vegetation. The first-named chemical, 2,4,5-T, has been withdrawn from use pending a final decision on its fate by EPA. Certain other chemicals, such as monuron trichloroacetate, serve as soil sterilants and may also be considered substitutes for creosote for certain end uses.

Fungicidal Uses

Creosote and coal tar are used as fungicides to protect cordage and canvas products. In addition to its preservative action, impregnation of these products with creosote and coal tar also imparts a degree of water repellency, which, in most cases, would be desirable. None of the alternatives available would have this secondary effect to the same extent as creosote, but there are products on the market with little or no fungistatic properties that could be used for this purpose.

Where fungicidal properties are the only requirement, the following products can be substituted for creosote in most situations.

Copper naphthenate
Zinc naphthenate
Copper naphthenate + penta
Zinc naphthenate + penta
Copper 8-quinolinolate
Copper naphthenate + copper oxide

All of these products would be applied in an oil or light petroleum solvent. Penta is now under RPAR.

Insecticidal, Miticidal, Larvicidal, and Repellent Uses

Creosote, coal tar, and/or neutral oil products are registered for use as insecticides, acaricides, arachnicides, and repellents for both animals and birds. Alternative chemicals and chemical formulations for control of the same pests are presented here. Sources of information are shown in the appropriate sections. In those instances where it was not possible to verify that a coal-tar distillate is actually used in an application for which it is registered, this fact is noted.

Animal Quarters

Alternative chemicals for control of animal parasites in animal quarters are shown below. All of the chemicals listed are reported to be at least as effective as coal-tar distillates and, unlike the latter products, may be applied directly to food animals (Anonymous, 1976). None of the coal-tar products of concern here was recommended by current technical literature for control of any of the pests listed.

<u>Pest</u>	<u>Site</u>	<u>Alternative</u>
Lice	Quarters for cattle, swine, sheep, and goats	Co-Ral [®] Crotoxyphos Ciovap [®] Ruelene [®] Dioxathion Malathion Methoxychlor Toxaphene - under RPAR Ronnel - under RPAR review
Ticks		Co-Ral [®] Crotoxyphos Ciovap [®] Dioxathion Malathion Ronnel - under RPAR review Toxaphene - under RPAR

For control of house flies in animal quarters, the following chemicals are recommended (Anonymous, 1976). Although neutral oil products are registered for this use, they were not included in this list of recommended chemicals. None of the live-stock experts contacted was aware of any current usage of coal-tar products for this or any other facet of pest control associated with food-animal production (Combs, 1979; Hidalgo, 1979; and McWhorter, 1979).

<u>Pest</u>	<u>Site</u>	<u>Alternative</u>
House fly	Animal quarters	Crotoxyphos Crotoxyphos 10% + Dichlorvos 2.5% - under RPAR review Diazinon Dichlorvos - under RPAR review Dimethoate - under RPAR Fenthion Malathion Rabon [®] Ronnel - under RPAR review

Each of the above products is applied as a spray (1 gallon/500 to 1,000 ft²) to walls, ceilings, and other surfaces. None is recommended for use in milk rooms. Some are recommended for use as the active ingredient in sweet baits.

Essentially the same chemicals as those previously listed are recommended for control of lice and mites in poultry houses, except that carbaryl is also used for this purpose. All chemicals are applied as a spray at the rate of 1 gallon/500 to 1,000 ft². Coal-tar derivatives were not included in any of the lists of recommended chemicals reviewed by the committee.

Animal Dip

A somewhat longer list of chemicals that may be considered as substitutes for coal-tar distillates is available for use on horses, mules, and other non-food animals.

<u>Pest</u>	<u>Site</u>	<u>Alternative</u>
Ticks	Horses and mules	Coumaphos
		Dioxathion
	Dogs	Malathion
		Toxaphene - under RPAR
		Carbaryl - under RPAR review
		Propoxur
		Malathion
		Methylated naphthalenes
		+ Ronnel (under RPAR review)
		and Diazinon
Lice	Horses, mules and dogs	Methoxychlor
		Methoxychlor
		Malathion
Fleas	Dogs	Toxaphene - under RPAR
		Pyrethrins
		Piperonyl butoxide - under RPAR review
		Carbaryl - under RPAR review
		Rotenone - under RPAR review
		Dichlorvos - under RPAR review
		Propoxur
		Malathion
		Methoxychlor
		Malathion
Mange mites		Benzyl benzoate
		Rotenone + - under RPAR review
		gamma isomer of BHC - under RPAR
		Sulfur + turpentine +
		pine tar oil + phenol
		Lindane - under RPAR

Coal-tar neutral oils products are included in the list of recommended chemicals and formulation for control of lice and mange mites on horses and mules and for control of fleas, ticks, and lice on dogs. Veterinarians contacted stated that these products are used extensively for these purposes, but each emphasized that one or more of the alternatives are equally as effective.

Larvicides

Neutral oil coal-tar acid combinations are registered as larvicides for the control of mosquitoes, screwworms, and fly larvae.

Mosquito larvae can be effectively controlled by covering the surface of the water in which they occur with a petroleum distillate of low volatility, such as No. 2 fuel oil (McWhorter, 1979). Alternatively, several pesticides, including malathion, lindane, or methoxychlor, dissolved in kerosene or No. 2 fuel oil may be

used. No evidence was made available to the Assessment Team that indicated neutral-oil products are actually used as a mosquito larvicide. On the contrary, the entomologists consulted on this matter stated that they have no knowledge of their use for this purpose.

Alternatives for control of screwworms in farm animals include coumaphos, ronnel, lindane in pine oil, and diphenylamine in benzene (Anonymous, 1976). No coal-tar distillate is included in the list of recommended control chemicals and formulations. Although there is indirect evidence that these products are used for screwworm control, animal pest experts contacted were not aware of their use in their respective geographical region for that purpose (McWhorter, 1979; Combs, 1979; and Hidalgo, 1979).

Maggots are the larval stage of various species of flies, including the common house fly. Neutral-oil products are registered for use in garbage containers, and for this site ronnel, methoxychlor, and orthodichlorobenzene are suitable alternatives. It is assumed that these or other pesticides may be used to control drain flies in grease traps and other sites where this pest occurs, but registration of alternatives is lacking.

Gypsy Moth Control

There are at present no alternatives to coal-tar distillates for the regulatory treatments of gypsy moth (Wood, 1979). An insecticide, diflubenzuron (Dimilin®), meets the criteria but is not registered for this use.

Repellent Uses

Bird Repellent

A blend of creosote and neutral oil is packaged and sold by a single company, Borderland Products, Inc., a subsidiary of Stanford Seed Company of Buffalo, New York (EPA Registration No. 7832-0001), for use as a crow repellent on seed corn. Contacts made with this firm indicate that this product, which has been produced and sold for over 50 years, is extensively used in an area extending from northeastern United States through Texas and along the Eastern Seaboard (Koepf, 1979). It is used only to a limited extent in the Midwest and West because of the absence of a crow problem. The only other company that holds a registration for the use of a coal-tar distillate as a bird repellent is Parson's Chemical Works, Inc., Grand Ledge, Michigan (Registration No. 1969-3301). This company stopped production of its repellent 2 years ago. A third product, (Sterling-Clark-Lurton Company, EPA Registration No. 9957-00004) the registration data for which inferred that it was used as a repellent and feeding depressant, is in fact sold only for wood-preserving purposes.

There are several products based on coal tar that can be used as alternatives for bird repellents. Data supplied by the EPA included copper oxalate as one such alternative, and it was confirmed that it is being sold for that purpose. The cost is comparable to that for the coal-tar product and application is simpler, as the chemical is applied as a powder. It, too, is packaged and sold by Borderland Products, Inc.

Mesuroil® (4-(methylthio)-3,5-xglyl methylcarbamate) is also reported to be widely used as a repellent on corn and other seed (Mann, 1979; and Mississippi State Univ., 1979). Having both insecticidal and bird-repellent characteristics, this

product is preferred by some planters over the formulation based on creosote and neutral oil, which serves only as a repellent. Mesurol is more expensive by a factor of three or four than either copper oxalate or coal-tar-based repellents (Koepf, 1979). It is produced under the trade name of Borderland Black by Borderland Products, Inc. (EPA Registration No. 7832-0004) and, except for cost, is considered to be a viable alternative for coal-tar-based products.

Tetramethylthiuram disulfide (thiram), a chemical sold under several trade names in the past, is apparently widely used as a bird, rodent, and deer repellent. Currently formulated and packaged by the Gustafson Company of Dallas, Texas (EPA Registration No. 7501-14-AA), and marketed under the trade name Gustafson 42-S, it is used to treat a variety of seed types and as a foliar spray to discourage browsing by deer and rabbits. It is reported to be effective as both a fungicide and a repellent (Mann, 1979; and Karaffa, 1979).

Anthraquinone has been successfully used as a bird repellent on pine seed in direct seeding of open lands in the South. Originally imported from Germany, the product was marketed as a bird repellent in the United States for a time by Winthrop Chemical Company of New York. It was later manufactured and sold by American Cyanamid. The chemical now is widely used in the paper industry and the principal manufacturer is Mobay Company of West Germany, which produces about 15,000 tons annually. The chemical is also used as a dye stuff, and is manufactured for this purpose in the United States by Tom's River Chemical Company of New Jersey, a subsidiary of Ciba Geigy.

Although anthraquinone is not currently registered for use as a bird repellent, it has been extensively tested for this purpose. It is being used in the South as treatment for pine seed preparatory to sowing in tree nurseries. Steps are being taken to register the chemical for use as a bird repellent.

Animal Repellent

Creosote is used as a horse repellent (Registration No. 928-00001), as explained elsewhere in this document, and is considered to be essential for that use by that facet of the animal industry concerned with raising and breeding of these animals.

The Assessment Team was unable to find alternative products registered for this use. The only other material registered for this purpose is anthracene oil (Reg. No. 299-183). However, if coal tar or creosote is canceled for this use, anthracene oil will no longer be available because it is a product of the coal-tar distillation (315°-355° C). While apparently not registered as an animal repellent, tetramethylthiuram disulfide is reportedly used as a foliar spray to discourage browsing by deer and other animals (Mann, 1979).

Insect Repellent

A single EPA registration (No. 14820-00001) exists for a coal-tar-based insect repellent. Recommended for use on human skin, this product is suppose to repel gnats, mosquitoes, and deer flies. The Assessment Team was unable to contact the manufacturer of this product, because there was no listing for the firm in the city where it was last located.

There are approximately 110 registrations for products that are potential alternatives for coal tar as an insect repellent. Of this number, 103 are based on N, N-diethyl-meta-toluamide either alone or in combination with other chemicals. An entomologist contacted attested to the effectiveness of this chemical as an insect

repellent, stating that it is the most effective chemical currently available (Brook, 1979).

Disinfectants

Alternative disinfectants for emulsifiable coal-tar disinfectants (containing neutral oil) can be divided into several groups. The groups are synthetic phenolics, quaternary ammonium compounds, iodophors, and halogens. There are many brand names for each type of alternative disinfectant available. Each product has a different proportion of up to eight active ingredients; therefore, listing the cost and biological activity of each of the several hundred products available would not be feasible.

A cost comparison was made for one brand of each disinfectant group. The costs were as follows per gallon of disinfectant based on the manufacturers' recommended dilution for general use:

Synthetic phenolic	\$0.10
Iodophor	0.05
Quaternary ammonium compound	0.01
Sodium hypochlorite (halogen)	0.02
Emulsifiable coal-tar derivative	0.19

Biological activity of disinfectants can be altered by many factors. Some of the major ones are bacterial agents, organic matter, disinfectant concentration, time of contact, and temperature. For any particular disinfectant use situation, the bacterial agent, temperature, and contact time would be constant regardless of which disinfectant was used. Therefore, the variables are concentration and level of organic matter (organic load) for alternative comparison. The dilution of disinfectant is recommended by the manufacturer and must be relied on to maintain disinfectant activity. The only difference between farm and ranch use versus general use is the organic load.

Organic matter influences the activity of all disinfectants. In the general use situation, the objects to be disinfected can be cleaned first to remove organic matter. Therefore, all the disinfectant types could be used, if the manufacturer makes claims for such use. As cleaning in farm and ranch use is difficult, disinfectants that are least affected by organic matter are required. Synthetic phenolics, which are related chemically to the cresols in emulsifiable coal-tar disinfectants, are the only alternatives not greatly affected by organic matter.

The alternative disinfectants, listed by group name, and emulsifiable coal-tar disinfectant are given in Table 98 with the relative effect caused by organic matter. Based on these data, only the synthetic phenolics would be suitable alternatives to neutral oil disinfectants in situations where an organic load is present.

Table 98.--Appropriate uses of disinfectants by type and the relative effect of organic matter

Disinfectant Type	Effectiveness ^a	Farm and Ranch Use ^b	General Use ^b
Emulsifiable coal-tar derivative	high	+	+
Phenolic	high	+	+
Iodophor	medium	±	+
Quaternary ammonium compound	low	-	+
Halogen	low	-	+

^a relative effectiveness of product in the presence of organic matter

^b + product usable in situation listed

± marginal usage in situations where organic load is present

- not usable in situations where organic load is present

In summary, alternative disinfectants are available with comparable effectiveness and at lower costs than coal tar distillates.

Summary of Biological Analysis of Creosote, Coal Tar, and Neutral Oils

Creosote, coal tar, and coal-tar neutral oil are registered for use for a large number of non-wood-preserving applications, the most common of which are of a herbicidal, fungicidal, insecticidal, and bactericidal nature. Neutral-oil products composed principally of neutral oil and coal-tar acids account for most of the volume used. Annual production is approximately 330,000 gallons of a concentrate typically consisting of 63% neutral oil, 15% tar acids, 14% soap, and 8% water. It is thought that considerably smaller quantities of creosote and coal tar are sold for non-wood-preserving uses, but definitive data on usage are lacking.

The varying definitions assigned to the term "neutral oil" are a source of confusion. In presuming against neutral oil, the EPA (Federal Register, 1978) defined this product as a mixture of hydrocarbons of coal-tar origin from which the tar acids and tar bases have been removed. Basically, this definition covers the neutral fraction of creosote and includes all the constituents shown in Table 75. The Assessment Team was unable to verify that a product conforming to this definition is produced or used in the United States. The coal-tar distillate referred to as "neutral oil" and used for the various types of applications referred to above is composed of 75% methylnaphthalenes and 25% coal-tar naphtha. It does not contain the high-boiling fractions encompassed in EPA's definition and for which there is some evidence of carcinogenicity in animals. This document addresses only that product that is currently being produced and used.

Application of coal-tar products used as disinfectants, fungicides, etc., is accomplished by spraying, wiping, sprinkling, mopping or immersing, the exact method depending upon the site and the pest. Method of application is probably the most important variable in determining exposure levels.

Data on the quantities of coal tar, creosote, and neutral oil sold for non-wood-preserving uses are not available. Similarly, the amount applied by type of end use (e.g. fungicide, disinfectant, insecticide, etc.) is unknown. In fact, only vague information on who uses these products, and in what quantities and for what purpose, was supplied by the producers and packagers; however, total annual consumption of products containing neutral oil is estimated to be approximately 330,000 gallons. This quantity converts to a volume of ready-to-use solution, equal to about 20 million gallons, assuming a dilution rate of 60:1. Considerably smaller quantities of creosote and coal tar--probably less than 20 thousand gallons annually--are thought to be used.

Neutral-oil products are sold by the manufacturers to retail outlets, primarily farm and ranch stores, jobbers, veterinary supply houses, and repackaging firms, among others. Only a limited amount--probably less than 5%--is sold directly to user groups. An estimated 65% of the total volume is used as a general disinfectant in animal production and for household and institutional applications. The balance is used as an insecticide and fungicide and for such site-specific applications as gypsy moth control, screwworm and ringworm wounds in animals, and animal dips for non-food animals. Some neutral-oil products are apparently still used for control of parasites in poultry houses, notwithstanding the fact that this use was canceled in 1972.

Specific examples of the application of coal-tar products for many of the uses for which they are registered were not uncovered by the Assessment Team. Exceptions are their uses as disinfectants in animal production, which was viewed by experts in the field as an important part of the total animal health program, and for control of the gypsy moth. The latter use constitutes a USDA regulatory treatment that is considered to be essential because of the economic importance of the gypsy moth and the fact that no alternative chemicals are registered for this use.

Data on efficacy of neutral-oil products for all except disinfectant uses are lacking. Coal-tar acids, the active ingredient in most neutral-oil products, have been shown to be highly effective as a general disinfectant, and non-neutral-oil formulations are designated by USDA as a regulatory treatment for the control of certain animal diseases, such as anthrax and tuberculosis.

Dermal and inhalation exposure at the point of manufacture of neutral-oil-containing formulations is judged to be small. Approximately two-thirds of the formulating companies have apparently met OSHA standards with regard to employee safety. A relatively small number of employees (estimated at less than 1,000) are directly involved in the manufacture and packaging of these products, and duration of exposure for those most directly involved in these activities is generally less than 100 hours per year.

The population of users is estimated at 100,000 to 500,000. Exposure varies with method of application, but is judged to be quite small on an annual basis because of infrequency of use and the low concentration--about 0.5%--of neutral oil in ready-to-use solutions.

Among coal-tar chemicals used as pesticides, the naphthalenes are unquestionably among those that are most subject to biological oxidation. Evidence amassed by numerous studies shows with a high degree of certainty that these chemicals are rapidly decomposed in both aquatic and terrestrial environments by several species of microorganisms. No evidence was uncovered by the Assessment Team that naphthalene compounds accumulate in plants. The fate of these compounds in the air is unknown, but it is assumed that they are broken down in part by photochemical oxidation and, upon settling to earth, by soil bacteria.

Economic Impact Analysis of Canceling Creosote, Coal Tar, and Neutral Oil Uses

Current Use Analysis

Creosote, coal tar, and neutral oil are organic chemicals derived from bituminous coal. These organic chemicals are used primarily as wood preservatives. Of the approximately 100 million gallons of creosote used annually, only 2% (about 2 million gallons) is consumed in non-pressure commercial thermal and soak treatments. An additional 0.05%, or 50,000 gallons, is used for maintenance treatments of utility poles in line. An additional 0.2%, or about 200 thousand gallons, is sold through retail outlets to homeowners and other groups for brush, dip, and spray applications. The balance, representing 97.75 million gallons or almost 98% of the total, is used in pressure wood treatment process.

In addition to preservative uses, these materials are employed in a wide variety of applications not related either to wood or wood preservation. These uses of creosote, coal tar, and neutral oils are listed below in the groupings shown:

1) Insect repellent	1 registration
2) Herbicide	1 registration
3) Fungicide for rope canvas, tarpaulins	1 registration
4) Mosquito larvicide	16 registrations
5) Insecticide for screwworm on horses, mules, and fungicide for ringworm on horses	2 registrations
6) Acaricide for mange mites on horses	2 registrations
7) Disinfectant--human	1 registration
8) Disinfectant--animal and animal quarters	406 registrations
9) Insecticide for lice and flies on horses, dogs, hog houses, sheep barns, dog kennels, and stables	7 registrations
10) Larvicide for drain flies and flies on garbage trucks	14 registrations
11) Arachicide for ticks in hog houses, sheep barns, dog kennels, horse stables, and on dogs	1 registration
12) Tree dressing	2 registrations
13) Bird repellent	1 registration
14) Horse repellent	1 registration
15) Gypsy Moth larvicide	3 registrations

Limitation of the Analysis

Although there are many registrations for non-pressure wood preservative uses, no usage data are available. Furthermore, the non-wood-use-products listed involve more than one site (for example, horses/dogs or agricultural premises/residential and institutional premises); therefore, it is not possible to determine the amount of active ingredient used per site.

Extent of Use

The first minor usage of these chemicals is as an insect repellent. Coal-tar distillates are used to a limited extent in the control of insects. There is one registration for this purpose (see Use Patterns and Efficacy). An extensive examination of the literature did not reveal any estimates of the extent of its use. Personal contacts did not provide any estimates of usage.

The second minor usage of these chemicals is as a herbicide. There is one registration for this use (Gibb, 1979). Turfgrass experts and weed scientists, as well as USDA personnel who were contacted, were not aware of any use of this product for that purpose (see Use Patterns and Efficacy).

The third minor use is as a fungicide on rope and canvas tarpaulins. There is only one registration for this use (Gibb, 1979). It is not a pesticide as such, but rather a preservative for tarpaulins and stack covers. In the case of rope, it also provides protection against decay (Cummings, 1979a). No estimates of the quantities of product used for this purpose are available.

The fourth minor usage of these chemicals is as a mosquito larvicide. There are 16 registrations for this purpose (Stapp, 1979). Blends of neutral oil and coal-tar acids are used to control the mosquito larvae in stagnant waters (see Use Patterns and Efficacy). The continued availability of these products for these uses is not vital, because effective alternative chemicals are registered and available.

The fifth minor usage is as an insecticide for screwworm on horses and mules and as a fungicide for ringworm on horses. There are two registrations for these use sites (Gibb, 1979), but data on quantities used are not available. The USDA, however, does not recommend coal tar derivative products for the control of lice, and recommendations for screwworm control were not available. No State recommendations are available listing these chemicals for screwworm control (Devine, 1979).

The sixth minor usage is as an acaricide for mange mites on horses. There are two registrations that control lice and psoroptic mange mite on horses. These products contain coal tar-neutral oils. There are over 10 chemicals registered for use for equine psoroptic mange mite control, and over 40 registered alternatives for lice control on horses. USDA recommendations for mange control on horses were not available. A listing of available State recommendations for mange lice and screwworm control is shown in Table 99. No State recommendations are available.

The seventh minor usage is as an insect repellent for use by humans. There is only one registration for this use (EPA Reg. No. 14820-1). It is a coal-tar-based insect repellent and is applied to exposed skin areas, except the forehead. The question of whether this use is properly an area of regulation by the Food and Drug Administration is currently under review by EPA.

The eighth use is as a disinfectant. Both coal tar and neutral oil-tar acid blends are the active ingredients that are used for this purpose. Disinfectant uses account for an estimated 50 to 80% of total production of those formulations containing neutral oils, and as such are the most important non-preservative uses of these products. The quantity used is estimated as 215,000 gallons of concentrate, or about 13 million gallons of ready-to-use solution per year. There are currently 406 separate site/pest registered uses of coal-tar distillates as disinfectants that contain both neutral oils and/or coal tar. Only 13 of these contain coal tar. It was assumed that about 65% of the total volume of coal-tar based pesticides is used

Table 99.--Summary of State and Federal recommendations for lice mange and screwworm control on horses^{a,b}

States/USDA	Carbaryl ^c	Coumaphos	Creosote ^d	Crotox- yphos	DDVP ^c	Diazinon	Dioxa- thion	Lindane ^d	Lindane ^d + Toxa- phene	Mala- thion	Meth- oxy- chlor	Meth- oxy- chlor + Mala- thion	Pyre- thrins + Piper- onyl Buto- xide	Ronnel ^e	Ruelene	Toxa- phene ^d
Arizona	L	L	--	--	--	--	L	L	--	--	--	--	--	S	--	--
California	--	S	--	L,S	L	--	--	L,S	--	L	--	--	L	--	--	--
Colorado	L	L	--	--	L	--	L	--	--	--	--	--	--	--	--	--
Connecticut	--	L	--	--	--	--	--	--	--	L	--	--	--	--	--	--
Florida	--	L,S	--	--	--	--	--	L,M	L	--	--	--	--	--	--	M
Illinois	--	L	--	--	--	--	--	--	--	L	--	--	--	--	--	--
Iowa	--	L,S	--	--	--	--	L	--	--	L	--	--	--	S	--	L,M
Maryland	--	L	--	--	--	--	--	--	--	L	--	--	--	--	--	--
Michigan	--	L	--	--	--	--	--	--	--	L	--	--	--	S	--	-- ^f
Mississippi	--	L	L ^f	--	--	--	L	--	--	L	--	L	--	--	--	L ^f
Missouri	--	L,S	--	--	--	--	L	M	--	L	--	--	--	--	--	--
New Jersey	--	L	--	--	--	--	--	--	--	L	--	--	--	--	--	--
New Mexico	--	L	--	L	--	--	--	M	--	L	--	--	--	--	--	M
Pennsylvania	--	L	--	--	--	--	--	--	--	L	--	--	--	--	--	L
South Carolina	--	L	--	--	--	--	--	--	--	L	--	--	--	--	--	--
Tennessee	--	L	--	--	--	--	--	--	--	--	L	--	--	L	L	L
Texas	L	L,S	--	--	--	--	L	S	--	--	--	--	--	--	--	--
Virginia	--	L	--	--	--	--	--	--	--	L	--	--	--	--	--	--
Washington	--	--	--	L	--	L	L	L	--	L	L	--	--	L	--	L
USDA	--	L	--	L	--	--	L	--	--	L	--	--	--	--	--	--

^a Sources: Arizona, 1978
California, 1972
Colorado, 1977
Connecticut, 1976
Florida, 1976
Illinois, 1976a
Iowa, 1978
Maryland, 1978
Michigan, 1975
Mississippi, 1975
Missouri, 1976
New Jersey, 1976
New Mexico, 1974
Pennsylvania, 1977
South Carolina, 1979
Tennessee, 1973
Texas, 1972, 1975
Virginia, 1978a
Washington, 1977
USDA, 1974b

^b L = lice
M = mange
S = screwworm

^c Pre-RPAR chemical.

^d RPAR chemical

^e Ronnel no longer being produced (Dow Chemical, 1979).

^f To control lice mange (Mississippi, 1975).

as disinfectants, but no quantity usage figures are available (see Use Patterns and Efficacy).

The ninth minor usage is as an insecticide on dogs and horses for control of lice and fleas, and in dog kennels, stables, and hog houses to control these pests. Two coal-tar neutral-oil products are federally registered for both lice and flea control on dogs, and another product containing coal-tar neutral oils is also registered for lice control. Over 80 alternatives are registered for use on dogs for lice and over 100 substitute pesticides are listed for flea control (EPA, 1976c). A summary of all State recommendations available for flea, lice, mite, and tick control on dogs is given in Table 100. The most frequently recommended chemicals for flea control are: carbaryl (a pre-RPAR chemical), coumaphos, DDVP (a pre-RPAR chemical), malathion, methoxychlor, and rotenone. The most frequently listed State recommended chemicals for lice control are carbaryl (pre-RPAR) and malathion. The United States Department of Agriculture does not recommend coal-tar/creosote/coal-tar neutral oils for fleas or lice on dogs (USDA, 1974b and 1976). Table 100 indicates the Federal recommendations for flea and tick control on dogs.

One coal-tar neutral-oil product is federally registered to control lice and psoroptic mange mite on horses, and another product containing coal-tar neutral oils is federally registered for lice control only. There are over 40 chemical alternatives registered for use on horses to control lice, and over 10 substitutes for equine psoroptic mange mite control. A summary of the available State recommendations dealing with lice, mange, and screwworm control is listed in Table 99 and earlier in this chapter. The most frequently recommended chemical alternatives for lice control are: coumaphos, dioxathion, malathion, and toxaphene (RPAR chemical). The USDA recommendations for lice control are: coumaphos, crotoxyphos, dioxathion, and malathion (USDA, 1974b).

The coal-tar-based pesticides are federally registered as disinfectants for animals and animal quarters and are used to control animal parasites such as fleas, lice, mites, and ticks in animal quarters. These products have been canceled for use on food animals, but are permitted in animal quarters and on nonfood animals such as dogs and horses (see Use Patterns and Efficacy). The State recommendations dealing with fleas, lice, mite, and tick control on various animal premises are given in Tables 102, 103, 104 and previously in this chapter. A summary of the approximate number of registered chemicals for selected animal premise sites and uses is given in Table 101.

The tenth minor use of these products is for control of maggots and flies in garbage trucks, where they serve as a larvicide and disinfectant. Neutral-oil products are also used to control drain flies and their maggots in drain lines, etc. The continued availability of these products for this use seems important, as no alternative is registered for drain fly control.

The eleventh minor use is as an arachicide for ticks in hog houses, sheep barns, dog kennels, and horse stables, and on dogs. This usage is covered in Tables 102, 103, and 104 and, along with the minor usage in category nine, is probably one of the most important non-preservative uses.

The twelfth minor usage is as a tree dressing. There are two registrations for creosote coal tar as a tree wound dressing. As early as 1932, it was observed that tars and creosotes were injurious to the growing layer at the margin of tree wounds. Toxicity tests show that fibrated asphalt paint plus creosote applied to tree wounds caused some consistent injury to cambium tissue at the margin of the wound and therefore reacts unfavorably on the tree's natural healing process (Cummings, 1979a).

Table 100.--Summary of State and Federal recommendations for flea, lice, mite, and tick control on dogs^{a,b}

States/USDA	Benzyl Benzoate	BHC ^c	Carbaryl ^d	Chlordane ^e	Chlorpyrifos	Coumaphos	Creosote ^f	Cythioate
Alabama	--	--	F,T	--	--	F,T	--	--
Arkansas	--	--	F,T	--	--	--	--	--
California	--	--	F,T	T	--	F	--	--
Illinois	--	--	F,T	--	--	--	--	--
Indiana	--	--	T	--	--	--	--	--
Iowa	--	--	F,L,T	--	--	F,L,T	--	--
Louisiana	--	--	F,T	--	--	--	--	--
Minnesota	--	--	F,T	--	--	T	--	--
Mississippi	M	F,M,T	F,L,T	F,L,M,T	--	--	F,L,T	F,T
Missouri	--	--	F,T	--	--	--	--	--
Montana	--	--	--	--	--	--	--	--
Nebraska	--	--	F,T,L	--	--	--	--	--
New Jersey	--	--	F	--	--	--	--	--
New Mexico	--	--	F	--	--	--	--	--
North Carolina	--	--	F,T	--	--	--	--	--
North Dakota	--	--	F,T	--	--	F,T	--	--
Ohio	--	--	T	--	--	--	--	--
Oklahoma	--	--	F,L,T	T	--	--	--	--
Pennsylvania	--	--	T	--	--	--	--	--
Rhode Island	--	--	T	--	--	--	--	--
South Dakota	--	--	T	--	--	F	--	--
Tennessee	--	--	F,T	--	--	F	--	--
Texas	--	--	F,T	--	F	--	--	--
Virginia	--	--	F,T	--	--	--	--	--
Washington	--	--	F	--	--	--	--	--
West Virginia	--	--	F	--	--	--	--	--
USDA	--	--	--	T	--	--	--	--

Table 100.--Summary of State and Federal recommendations for flea, lice, mite, and tick control
on dogs^{a,b}--continued

States/USDA	Diazinon	Dioxathion	DDVP ^d	Lindane ^f	Malathion	Methoxy- chlor	Methylated Napthalenes + Ronnal + Diazinon	Propoxur
Alabama	--	--	F,T	--	F	--	--	--
Arkansas	--	--	--	--	F,T	F	--	--
California	--	--	F,T	F,T	F,T	--	--	--
Illinois	--	--	--	--	F,T	--	--	--
Indiana	--	--	--	--	--	--	--	--
Iowa	--	--	F,L,T	--	F,L,T	--	--	--
Louisiana	--	--	--	--	--	--	--	--
Minnesota	--	--	F,T	--	F,T	F,T	--	--
Mississippi	--	--	F	F,L,M,T	F,L,T	F,L,T	F,L,T	F,T
Missouri	--	--	--	--	F,T	--	--	--
Montana	--	--	--	F,L,T	F,L,T	F,L,T	--	--
Nebraska	--	--	F,L,T	--	F,L,T	--	--	--
New Jersey	--	--	--	--	--	--	--	F
New Mexico	--	--	--	--	F	--	--	--
North Carolina	--	--	--	--	F,T	--	--	--
North Dakota	--	--	F,T	--	F,T	--	--	--
Ohio	--	--	--	--	T	--	--	--
Oklahoma	--	--	F,L,T	M,T	F,L,T	--	--	--
Pennsylvania	T	--	--	--	--	--	--	T
Rhode Island	--	--	--	--	F	F	--	F
South Dakota	--	--	F	--	F	--	--	F
Tennessee	--	F,T	F	--	--	--	--	--
Texas	F	--	F	--	T	--	--	--
Virginia	--	--	--	--	T	F	--	F
Washington	--	--	F	--	F	--	--	--
West Virginia	--	--	--	--	--	--	--	--
USDA	T	--	--	T	F,T	F	--	--

Table 100.--Summary of State and Federal recommendations for flea, lice, mite, and tick control
on dogs^{a,b}--continued

States/USDA	Pyre- thrins	Pyrethrins + Piperonyl	Butoxide	Pyrethrins + Synergist	Ronnel ^g	Rotenone	Silica Aerogel Formulations	Sulfur	Trichlorfon
Alabama	--	--	--	--	--	--	--	--	--
Arkansas	--	--	--	--	--	F,T	--	--	--
California	--	--	--	--	--	T	F,T	--	--
Illinois	F,T	--	--	--	--	--	--	--	--
Indiana	--	--	--	--	--	--	--	--	--
Iowa	--	--	--	--	--	F,L	--	--	--
Louisiana	F,T	--	--	--	--	F,T	--	--	--
Minnesota	--	--	--	T	--	F,T	--	--	T
Mississippi	--	F	--	--	--	M,F	--	M	--
Missouri	--	--	--	--	--	T	--	--	--
Montana	--	--	--	F,L,T	--	F,L,T	--	--	--
Nebraska	F,L,T	--	--	--	--	F,L,T	--	--	--
New Jersey	--	--	--	--	--	--	--	--	--
New Mexico	--	--	--	--	--	F	--	--	--
North Carolina	F	--	--	--	--	--	--	--	--
North Dakota	--	--	--	--	--	--	--	--	--
Ohio	--	--	--	--	--	T	--	--	--
Oklahoma	--	--	--	--	T	--	--	--	--
Pennsylvania	--	--	--	--	--	T	--	--	--
Rhode Island	--	--	--	--	--	F,T	--	--	--
South Dakota	--	--	--	--	--	--	--	--	--
Tennessee	--	--	--	--	--	--	--	--	--
Texas	--	F,T	--	--	T	--	--	--	--
Virginia	--	--	--	--	--	F,T	--	--	--
Washington	--	--	--	--	--	F	--	--	--

Table 100.--Summary of State and Federal recommendations for flea, lice, mite, and tick control
on dogs^{a,b}--continued

States/USDA	Pyre- thrins	Pyrethrins + Piperonyl	Butoxide	Pyrethrins + Synergist	Ronnel ^g	Rotenone	Silica Aerogel Formulations	Sulfur	Trichlorfon
West Virginia	--	--	--	--	--	F	--	--	--
USDA	--	--	--	--	--	--	--	--	--

^a Source: Alabama, 1975 Iowa, 1978 Nebraska, 1975 Oklahoma, 1975 Texas, 1979
Arkansas, 1975 Louisiana, 1976 New Jersey, 1976 Pennsylvania, 1977 USDA, 1976a (fleas)
California, 1970 Minnesota, 1975 New Mexico, 1973 Rhode Island, 1974 and 1974b (ticks)
and 1974 Mississippi, 1975 North Carolina, 1977 and 1974a Virginia, 1978
Illinois, 1976 Missouri, 1976 North Dakota, 1977 South Dakota, 1976 Washington, 1979
Indiana, 1976 Montana, 1975 Ohio, 1978 Tennessee, 1975 West Virginia, 1976

^b F = fleas
L = lice
M = mites
T = ticks

^c Lindane now being substituted for BHC (EPA/USDA, 1978).

^d Pre-RPAR chemical.

^e Canceled for livestock uses, December 31, 1980 (EPA, 1978a).

^f RPAR chemical.

^g Ronnel is no longer being produced (Dow Chemical, 1979).

Table 101.--Approximate number of registered chemicals for selected animal premise sites and uses^a

Site	Bacteria	Fleas	Fungi	Lice	Mites	Ticks
Livestock premises	81	-- ^b	32	--	--	--
Poultry buildings	--	21	--	18	20	13
Poultryhouse premises	82	--	64	--	--	--
Kennels	27	25	--	10	--	17
Stables	33	11	--	3	3	4
Hogbarns/houses/ parlors/pens	--	10	--	11	5	12

^a Sources: EPA, 1976c.

^b = not applicable/not given.

Table 102.--Summary of State and Federal recommendations for flea, lice, and tick control on dog premises^{a, b}

[illegible]

Table 102.--Summary of State and Federal recommendations for flea, lice, and tick control on dog premises^{a,b}--continued

States/USDA	DDVP ^d	DDVP ^d + Pyrethrins + Synergist	Heptachlor ^f	Lindane ^g	Malathion	Methoxychlor	Methyl- carbamate	Methyl- carbamate + Pyrethrins	Methylated Naphthalenes + Ronnel + Diazinon
Alabama	--	--	--	--	F,T	--	--	--	--
Arkansas	--	--	--	--	F,T	--	--	--	--
California	F,T	--	--	F	F	--	--	--	--
Illinois	--	--	--	--	--	--	--	--	--
Indiana	T	T	--	--	--	--	--	--	--
Iowa	F,T	--	--	--	F,T	--	F,T	--	--
Louisiana	--	--	--	--	F,T	--	--	--	--
Minnesota	--	--	--	--	F	--	F	--	--
Mississippi	--	--	--	F,T	F,L,T	--	--	--	F,L,T
Missouri	--	--	--	--	F,T	--	--	--	--
Nebraska	--	--	--	--	F	F	--	--	--
New Jersey	--	--	--	--	F	--	--	--	--
New Mexico	--	--	--	--	F,T	--	--	--	--
North Carolina	F	--	--	--	F,T	--	--	--	--
North Dakota	--	--	--	--	F	--	--	--	--
Ohio	--	--	T	--	T	--	--	--	--
Oklahoma	--	--	--	T	F,L,T	--	--	--	--
Pennsylvania	--	--	--	--	F	--	--	--	--
Rhode Island	F	--	--	--	F	F	--	--	--
South Carolina	--	--	--	F	F	--	--	--	--
South Dakota	F	--	--	--	F,T	--	--	--	--
Tennessee	--	--	--	--	F,T	--	--	--	--
Texas	--	--	--	--	--	--	--	--	--
Virginia	F,T	--	--	--	F,T	--	--	--	--
Washington	F	--	--	--	--	--	--	--	--
West Virginia	--	--	--	--	F	--	--	--	--
USDA	--	--	--	--	F	F	--	--	--

Table 102.--Summary of State and Federal recommendations for flea, lice, and tick control on dog premises^{a,b}--continued

States/USDA	Naled	Piperonyl butoxide	Propoxur	Pyrethrins	Pyrethrins + Piperonyl Butoxide	Pyrethrins + Synergist	Resmethrin	Ronnel ^h	Ronnel ^h Pyrethrum + Piperonyl Butoxide	Sorptive Dust
Alabama	--	--	--	--	--	--	--	F	--	--
Arkansas	--	--	T	--	--	--	--	F	--	--
California	--	--	--	--	--	--	--	F	--	F
Illinois	--	--	--	F,T	--	--	--	--	--	--
Indiana	--	--	--	--	--	T	--	--	--	--
Iowa	--	--	--	--	--	--	--	--	--	F,L,T
Louisiana	--	--	--	--	--	--	--	--	--	--
Minnesota	--	--	F,T	--	--	--	--	F	--	--
Mississippi	--	F,T	F,T	--	F	--	--	F	F,T	F
Missouri	--	--	T	--	--	--	--	--	--	T
Nebraska	--	--	T	--	--	--	--	--	--	--
New Jersey	--	--	--	--	--	--	--	F	--	--
New Mexico	--	--	--	--	--	--	--	F	--	F
North Carolina	--	--	T	--	--	--	--	T	--	--
North Dakota	--	--	--	--	--	--	--	F	--	--
Ohio	--	--	T	--	--	--	--	--	--	--
Oklahoma	--	--	--	--	--	--	--	F,L,T	--	--
Pennsylvania	--	--	T	F	--	--	F	F	--	F,T
Rhode Island	--	--	--	--	--	--	--	--	--	--
South Carolina	F	--	--	F	--	--	--	F	--	--
South Dakota	--	--	F	--	--	--	--	F,T	--	--
Tennessee	--	--	--	--	--	--	--	F	--	--
Texas	--	--	--	--	--	--	--	F,T	--	--
Virginia	--	--	F,T	--	--	--	--	--	--	F
Washington	--	--	F	F	--	--	F	F	--	F
West Virginia	--	--	--	--	--	--	--	F	--	--
USDA	--	--	--	F	--	--	--	F	--	--

^a Sources: Alabama, 1975 Iowa, 1978 Nebraska, 1975 Ohio, 1978 South Dakota, 1976 West Virginia, 1976
Arkansas, 1975 Louisiana, 1976 New Jersey, 1976 Oklahoma, 1975 Tennessee, 1975 USDA, 1976a
California, 1974 Minnesota, 1975 New Mexico, 1973 Pennsylvania, 1977 Texas, 1979
Illinois, 1976 Mississippi, 1975 North Carolina, 1977 Rhode Island, 1974 Virginia, 1978
Indiana, 1976 Missouri, 1976 North Dakota, 1977 South Carolina, 1979 Washington, 1979

^b F = fleas; L = lice; T = ticks

^c Lindane now being substituted for BHC (EPA/USDA, 1978).

^d Pre-RPAR chemical.

^e Livestock uses canceled (EPA, 1978a).

^f Livestock uses canceled, July 1, 1983 (EPA, 1978a).

^g RPAR chemical.

^h Ronnel no longer being produced (Dow Chemical, 1979).

Table 103.--Summary of State and Federal recommendations for insect, mite, and tick control on horse stables^{a,b}

State	Diazinon	Dimethoate	Fenthion	Malathion	Ronnel ^c	Tetrachlorvinphos + DDVP ^d	Toxaphene ^e
Florida	--	--	--	--	--	T	--
Michigan	I,M	I,M	I,M	I,M	I,M	I,M	--

^a Sources: Florida, 1976
Michigan, 1975

^b I = insect; M = mites; T = ticks

^c Ronnel no longer being produced (Dow Chemical, 1979).

^d Pre-RPAR chemical.

^e RPAR chemical.

Table 104.--Summary of State and Federal recommendations for lice and mite control on hog premises^{a,b}

States/USDA	Coumaphos	Fenthion	Malathion	Methoxychlor	Ronnel ^c	Tetrachlorvinphos
Arizona	L	--	L	--	L	L
Colorado	L	--	--	--	--	L
Iowa	--	--	L	--	--	L
Kansas	--	--	L	--	L	--
Michigan	L	--	--	--	--	--
Mississippi	L	L	L,M	L	L	--
Missouri	--	--	--	--	L	--
Montana	--	--	--	--	L	--
North Carolina	--	--	--	--	L	--
North Dakota	--	--	--	--	L	--
Pennsylvania	--	--	L	--	L	L
South Carolina	--	--	--	--	--	L
South Dakota	--	--	--	--	L	--
Texas	--	--	--	--	L	--
Washington	--	--	--	--	L	--
West Virginia	--	--	--	--	L	--
USDA	--	--	--	--	L	--

^a Sources: Arizona, 1978
Colorado, 1977
Iowa, 1978
Kansas, 1974
Michigan, 1975
Mississippi, 1974 and 1974a
Missouri, 1976
Montana, 1975
North Carolina, 1977
North Dakota, 1977
Pennsylvania, 1977
South Carolina, 1979
South Dakota, 1976
Texas, 1975
Washington, 1977
West Virginia, 1977
USDA, 1974b

^b L = lice; M = mites

^c Ronnel no longer being produced (Dow Chemical, 1979).

The thirteenth minor usage is as a bird repellent. Creosote is registered as a bird repellent for use on corn. Also registered are copper oxalate, Mesurol[®], and thiram. State recommendations dealing specifically with crow repellents on corn were unavailable.

Data for the quantity of bird repellent applied nationwide were not available. For illustrative purposes, Table 105 shows the amount of creosote and its alternatives used on a per-bushel basis.

Table 105.--Pounds of creosote and alternatives applied per bushel of seed corn^{a,b}

Chemical	Pounds Formulation Per Bushel	Percent Formulation	Pounds a.i. Per Bushel
Creosote	1/2	31.33	0.16
Copper oxalate	1/2	4.0	0.02
Mesurol [®]	1/2	50.0	0.25
Thiram	1/2	42.0	0.21

^a Source: EPA, 1976c.

^b One bushel is equal to approximately 56 pounds seed corn.

Although difficult to calculate accurately, 1 bushel of seeds is required for approximately 4 to 5 acres depending upon row size, seed size, and geographic area.

The following data illustrate the difference in chemical costs on a per bushel basis:

Chemical	Cost/Pound Dollars	Pounds/Bushel	Cost/Bushel Dollars
Creosote	2.10	1/2	1.05
Copper oxalate	2.10	1/2	1.05
Mesurol [®]	11.50	1/2	5.75
Thiram	2.60	1/2	1.30

Although Mesurol[®] and thiram are more expensive per bushel, copper oxalate is precisely the same price as creosote. Therefore, a suspension of creosote should not create any cost impact (Boisvert, 1979).

A number of nonchemical alternatives are also used for crow repellents. Exploders, traps, nets, and broadcasting amplified alarm or distress calls have proven to be effective mechanical means of control.

The fourteenth minor usage is as a horse repellent. Creosote oil is registered for use on wood stalls, mangers, gates, fence rails, posts, trees, trailer sides, and similar wooden structures, to prevent horses from biting, gnawing, or licking on their stalls and other wood the animals can come into contact with. Anthracene oil

is also federally registered for use on wood to protect against horse cribbing. This product, while also a coal-tar distillate, was not RPAR'd and presumably will remain available if creosote is canceled for this use, cuts of which are used in preparing commercial grades of creosote.

A local horse supplies store indicated that there are alternatives to creosote and anthracene oil. Federal registration of these products could not be verified by the Pesticide Product Information on Microfiche (EPA, 1976c). The State and United States Department of Agriculture recommendations available did not list any pesticides to prevent horse cribbing.

There are about 8.5 million horses in the United States and 3.2 million horse owners (American Horse Council, 1979). It is very difficult, however, to determine the extent of creosote oil use for horse cribbing. It is probable that usage is under 100,000 gallons annually (Devine, 1979a).

A horse's chewing, biting, and/or licking actions on the wood can lead to a more rapid deterioration of a wooden structure than would occur naturally; it also destroys the aesthetic appearance of the structure. Cribbing of trees can lead to destruction of the protective bark, and hence cause permanent damage to the trees.

The price per quart of various size containers of creosote and anthracene are shown in Table 106. Since equal amounts of these pesticides cover the same square footage of wood, comparison of the per-quart prices of the products indicates that all sizes of anthracene oil are less expensive than the creosote oil.

Table 106.--Price comparison of creosote oil and anthracene oil horse cribbing products^a

Pesticide	Number of Containers	Container Size	Price per quart
			Dollars
Creosote oil products	1	1 gallon	2.40
	1	5 gallons	2.26
	2 or more	5 gallons	1.87
	1	35 gallons	1.47
	1	55 gallons	1.45
Anthracene oil products	1	1 quart	1.09
	1	1 gallon	1.09
	1	5 gallons	.83
	1	55 gallons	.57

^a Source: Devine, 1979a.

Comparative efficacy data dealing with creosote oil and anthracene oil were not available. Discussions with manufacturers of creosote oil and anthracene oil horse cribbing products indicated that both pesticides will remain effective for several years. Also, equal amounts of both products cover the same area of wood. Therefore, it was assumed that both pesticides are equally efficacious.

The final and fifteenth minor usage is as a gypsy moth control. For a number of years a part of the control of the gypsy moth has focused control efforts on seeking out and destroying egg masses. These eggs, which are deposited on almost any surface above ground to which they may be attached, can often be found in areas of known infestation by diligent searching. Efforts have focused on controlling these egg masses on any materials that may be moved from the infested area to areas where new infestations may become established.

One standard practice has been to search out on mobile homes, logs, or other materials which will be moved, vehicles and similar items, any egg mass deposits that require control. Control is then accomplished by scraping the visible egg masses clean of the surface. For those areas where egg masses may be hidden or difficult to reach, creosote has been applied, usually by brush, to kill these deposited eggs. Typically, an egg mass may require from one-half to one teaspoon of concentrated creosote to assure control.

Creosote is vital for the control of these gypsy moth egg masses, because there is no registered alternative (Wood, 1979). Thousands of applications are made each year to stone and quarry products, timber and timber products, mobile homes and recreational vehicles, and trees and shrubs (USDA, 1976a; and Kennedy, 1979). It is and has been used extensively and repeatedly in 17 States (Kennedy, 1979).

In early times, DDT dust was used and was considered very effective. More recently, carbaryl has been used in areas where creosote was felt to be unsafe because of fumes. Because carbaryl has very little residual effect, however, it is not believed to be as effective. Research has continued to seek alternatives to creosote at the Otis Air Force Base Laboratory in Massachusetts, which is the focal point for most, if not all, research on control of the gypsy moth. This research laboratory is jointly operated by APHIS and the U.S. Forest Service. Recently, this laboratory discovered that a number of common household detergents are extremely effective in killing deposited eggs of the gypsy moth. In addition, efficacy has been found by the use of "light water," a product often used as a fire retardant. As these materials have widespread use for other purposes and are not registered pesticides, the question has been raised as to whether they may be used to control insect pests without the normal registration process (Mattson, 1979).

Summary

In this analysis of the 15 minor uses of creosote, coal tar, and neutral oils for non-wood-preserved uses, only five uses are significant; of these, four have either no alternative or the alternatives are not effective. One of these uses is as a disinfectant in animal quarters (stables, dog kennels, hog houses, etc.). The alternatives available for this use, except synthetic phenolic compounds, are not effective because they become inactive when they come in contact with animal waste. When creosote and coal tar are applied in animal quarters and come in contact with organic material, they remain active and continue to disinfect.

The continued use of neutral-oil products for control of drain flies is also important, because there are no alternative registered chemicals available for control of this pest.

Yet another use for which no registered alternatives are available is the application of coal-tar products (creosote and anthracene oil) to wood and plants to prevent cribbing by horses. These products are effective, and their continued use is supported by horse owners.

Another minor use that is strongly supported by the user community is as a bird repellent. Although there are alternatives, the user community reports that creosote is very effective. This use may, however, be based on tradition.

The final use is one in which there is no other registered alternative. It is as a larvicide in control of gypsy moth egg masses. Creosote, which is used extensively throughout 16 States, is the only registered chemical means of control of this pest, and is used when manual control are not possible.

There appear to be many alternatives for the other pesticide uses of coal tar and neutral oil. These alternatives have been recommended by the States and the USDA. Evidence of the usage of creosote, coal tar, and neutral oil in these applications was not found, despite an intensive investigation. As coal-tar distillates are apparently not being used in these applications, the benefits of their continued registration for these sites are assumed to be insignificant.

Summary of Economic Impact Analysis of Canceling Creosote, Coal Tar, and Neutral Oil

A. USES:

Creosote, coal tar, and neutral oils are registered pesticides for use in a wide variety of applications not related to either wood or wood preservation. These uses include: 1) Insect Repellent; 2) Herbicide; 3) Fungicide for rope canvas and tarpaulins; 4) Mosquito larvicide; 5) Insecticide for screwworm on horses and mules, and as a fungicide for ringworm on horses; 6) Acaricide for mange mites on horses; 7) Disinfectant-human habitation; 8) Disinfectant-animal and animal quarters; 9) Insecticide for lice and flies on horses, dogs, hog houses, sheep barns, dog kennels, and stables; 10) Larvicide for drain flies and flies on garbage trucks; 11) Arachicide for ticks in hog houses, sheep barns, dog kennels, horse stables, and on dogs; 12) Tree dressing; 13) Bird Repellent; 14) Horse Repellent; and 15) Gypsy moth larvicide.

B. MAJOR PESTS CONTROLLED:

The uses described above are minor compared with the major uses as a wood preservative. Among these minor uses, however, there are only five that are significant. They are as follows: Control of drain flies; and gypsy moth control; (these two have no registered alternatives) horse cribbing; disinfectant in animal quarters; and as a bird repellent. (These latter three have strong user support, although there are effective registered alternative pesticides for control).

C. ALTERNATIVES:

Major registered chemicals:

RPAR: Two of the most significant uses described above have no effective registered alternatives.

Non-RPAR: Registered alternatives exist for the other three significant uses. For the remaining 10 minor uses, effective registered alternatives exist or the registered product is not effective, or there is no significant usage of the product containing creosote, coal tar, or neutral oils.

Non-chemical controls:

There is no non-chemical alternative control for any of the disinfectant uses in animal quarters, control of drain flies, control of cribbing, and use as bird repellents; however, hand scraping is of limited use in control of gypsy moth egg masses.

Comparative performance:

Effectiveness of alternatives to creosote, coal tar, and neutral oils pesticide formulations varies depending upon which of the 15 categories of uses are considered; however, generally all, except two of the five most significant uses, have alternatives that are equally or more effective.

Comparative costs:

The costs of using creosote, coal tar, and neutral oils are higher than those associated with the use of alternatives, because these alternatives are either equally as effective or there is no significant usage of the creosote, coal tar, or neutral oil product.

Conclusions:

There will be no significant economic impact if creosote, coal tar, and neutral oils are no longer available for use in 10 of the minor use categories. There may be resistance to discontinuance in two other minor uses based on traditional usage habits; but, only in the five categories mentioned above, will there be significant impacts.

D. EXTENT OF USE:

Although the non-wood preservative uses of creosote, coal tar, and neutral oils are very minor in terms of volume, they are essential for the two non-wood preservative uses identified previously for which alternatives do not exist. No published data are available on extent of use; nevertheless, as a result of an industry response to a mail survey, as well as telephone interviews with managers of farm cooperatives, a distinction was made between these many uses and suggested that over 95% of the production of neutral oils (330 thousand gallons of various formulations) went for farm and ranch uses and that disinfectant uses are the most important on

these sites. A relatively small amount of neutral oils is used in the gypsy moth control program. Its use, however, is essential, because there is no registered alternative and the insect is capable of causing extensive damage to both hardwood and coniferous forests, as well as to shrubs and other plants used for landscaping purposes.

E. ECONOMIC IMPACTS:

User:

It is estimated that with the use of creosote, coal tars, and neutral oils as a disinfectant in animal quarters, and for control of drain flies and gypsy moth, significant savings occur in animal husbandry, vector control, and forestry management. The economic impact of cancellation of the use of creosote, coal tar and neutral oils is unknown, but because no alternatives are registered for drain fly and gypsy moth control, their continued use is important; thus the economic impact of cancellation would be very significant.

Market, consumer,
macro-economics:

Not available.

F. SOCIAL/COMMUNITY IMPACTS:

None.

G. LIMITATIONS OF THE ANALYSIS:

Magnitude of use of creosote, coal tar, and neutral oils by site is unknown; therefore, there are insufficient data for usage estimates of pesticides by the 15 minor non-wood preservative uses, and economic impact of cancellation cannot be quantified.

H. PRINICIPAL ANALYST AND DATE:

Robert O'Brien, Economist
Economic Analysis Branch
Benefit and Field Studies Division
Office of Pesticide Programs
EPA
May, 1980

REFERENCES

- Aboul-Ela, M. M., and C. S. Miller. 1965. Studies of Arsenic Acid Residues in Cotton. Texas Agric. Exp. Stn. MP 771.
- Aivazian, T. H. 1979. Personal Communication. Nov. 17. Reedley, Calif.
- Alabama. 1975. Alabama Insect Control Guide. Coop. Ext. Serv., Auburn Univ., Auburn, Ala.
- Alden, J. C. 1978. Personal Communication. Woolfolk Chem. Works, Inc., Ft. Valley, Ga.
- Alden, J. C. 1980. Personal Communication. Jan. 14. Woolfolk Chem. Works, Inc. Ft. Valley, Ga.
- Alford, D. S. 1980. Personal Communication. The Greens Country Club, Oklahoma City, Okla.
- Alford, H. G. 1979. Personal Communication. Coop. Ext. Serv., Univ. of Calif., Davis, Calif.
- American Horse Council. 1978. Personal Communication. Sept. 25. U.S. Environ. Prot. Agency, Wash., D.C.
- AWPI. 1979. American Wood Preservers Institute's response to EPA Position Document 1. Vol. III. Exposure Data Relating to Use of Creosote/Coal Tar Solutions as Wood Preservatives. Am. Wood Pres. Inst., McLean, Va.
- Ames, P. B., A. D. Brewer, and W. S. McIntire. 1974. UNI-N-252: A New Harvest-Aid Chemical. Proc. Beltwide Cotton Prod. Res. Conf. p. 61-62.
- Andris, H. L. 1979. Personal Communication. Oct. 16. Coop. Ext., Univ. Calif., Fresno, Calif.
- Anonymous. 1971. Virucidal Testing of Disinfectants. Microbiology Services, Natl. Animal Dis. Lab., Ames, Iowa. Mimeo. 4 p.
- Anonymous. 1976. Insect Control Guide. Entomol. Dept. Coop. Ext. Serv., Miss. State Univ., State College, Miss.
- Anonymous. 1978. Cresylic Disinfectant as Permitted Disinfectants: Specifications. Fed. Reg. 9CFR, Part 71.11.
- Anonymous. 1978a. Substances or Materials Allowed as Permitted Disinfectants. Fed. Reg. 9CFR, Part 71.10.
- Arizona. 1978. 1977-1978, Livestock Pest Control, College of Agric. Coop. Ext. Serv., Univ. of Ariz., Tucson, Ariz.
- Arkansas. 1975. Insecticide Recommendations for Arkansas. Coop. Ext. Serv., Univ. of Ark., Fayetteville, Ark.

- Attrep, M., D. W. Efurud, and S. G. Tribble. 1975. Seasonal Variation of Atmospheric Arsenic in a Cotton Growing Region. *Texas J. Sci.* 26:549-552.
- Baker, R. H., Jr. 1977. Quality Status of Florida's Drinking Water Systems. *Proc. Workshop on Florida Water Problems*. Fla. Sec. Am. Soc. Civil Eng., Univ. S. Florida, Tampa, Fla.
- Bashford, L. L. 1973. Heat Inputs to Cotton Plants. *Diss. Abstr. Int.*, p. 5786-B.
- Basinger, A. J. 1927. The Eradication Campaign Against the White Snail (*Helix pisana*) at La Jolla, Calif. *Monthly Bull. Calif. Dept. of Agric.*, Sacramento, Calif. p. 51-77.
- Basinger, A. J. 1931. The European Brown Snail in California. *Calif. Agric. Exp. Stn. Bull.* 515. 22 p.
- Belas, M. R., A. Zachery, D. Allen, B. Austin, and R. R. Colwell. 1979. Microbial Colonization of Naphthalene/Creosote-Treated Wood Pilings in a Tropical Marine Environment. *Proc. Am. Wood-Pres. Assoc. Preprint*. 8 p.
- Besthoff, W. W. 1979. Personal Communication. Dec. Faesv and Besthoff, Inc. Edgewater, N.J.
- Boisvert, E. 1979. Personal Communication. Sept. 20. U.S. Environ. Prot. Agency., Wash., D.C.
- Bonnett, L. O. 1926. A Promising Remedy for Black Measles of the Vine. Circular 303, Univ. Calif., College of Agric., Berkeley, Calif. 10 p.
- Bowers, K. W., R. L. Sisson, B. E. Bearden, A. N. Kasimatis, L. A. Horel, and A. D. Reed. 1978. Sample Costs to Establish and Produce Wine Grapes in the North Coast Counties. 1978 Spec. Publ. 3086. Div. Agric. Sci., Univ. of Calif., Berkeley, Calif.
- Bradicich, R., N. E. Foster, F. E. Hons, M. T. Jeffus, and C. T. Kenner. 1969. Arsenic in Cottonseed Products and Various Commodities. *Pestic. Monit. J.* 3:139-141.
- Brendel, T. P., and C. S. Miller. 1978. Alternatives to Desiccation. *Proc. Belt-wide Cotton Res. Conf.*
- Brints, N. 1979. Various Crop Production Budgets Prepared for the Rolling Plains Region. *Texas Agric. Ext. Serv.*, Vernon, Tex.
- Brook, T. 1979. Personal Communication. Entomol. Dept., Miss. State Univ., State College, Miss.
- Buehling, N. D. 1980. Personal Communication. Mar. 31. San Luis Rey, Calif.
- Burkholder, M. A. 1978. Personal Communication. Aug. 25. Trans-Pecos Cotton, Assoc. Pecos, Tex.
- Burrus, R. P. Jr., and D. M. Sargent. 1976. Technical and Microeconomical Analysis of Arsenic and Its Compounds. *Environ. Prot. Agency* 560/6-76-016. Versar Inc., Springfield, Va. 242 p.

- Butler, R. 1978. Personal Communication. Dec. 4. Wolfe City, Tex.
- California. 1970. Common Ticks Affecting Dogs. Coop. Ext. Serv., Univ. Calif., Berkeley, Calif.
- California. 1972. Control of External Parasites of Livestock, 1972-1973. Coop. Ext. Serv., Univ. Calif., Berkeley, Calif.
- California. 1974. Flea Control in and Around the Home. Coop. Ext. Serv., Univ. Calif., Berkeley, Calif.
- California Dept. of Food and Agric. 1975. Pesticide Use Rep., Sacramento, Calif.
- California Dept. of Food and Agric. 1976. Pesticide Use Rep., Sacramento, Calif.
- California Dept. of Food and Agric. 1977. Pesticide Use Rep. by Commodity, Sacramento, Calif.
- California Dept. of Food and Agric. 1978. Pesticide Use Rep., Sacramento, Calif.
- Caratan, M. 1979. Personal Communication. Oct. 1. M. Caratan, Inc., Delano, Calif.
- Carman, G. E. 1979. Personal Communication. Aug. 16. Univ. Calif., Riverside, Calif.
- Carman, G. E. 1979a. Personal Communication. Oct. 26. Univ. Calif., Riverside, Calif.
- Carman, G. E., and J. L. Passas. 1979. Unpublished results. Univ. Calif., Riverside, Calif.
- Cathey, G. W. 1976. Evaluation of TD 1123 as a Harvestaid Chemical on Cotton. Proc. Beltwide Cotton Prod. Res. Conf. (Abstr.). p. 49.
- Cathey, G. W., and H. R. Barry. 1977. Evaluation of Glyphosate as a Harvestaid Chemical on Cotton. Agron. J. 69:11-14.
- CCLRS. 1975. California's Principal Crop and Livestock Commodities. Calif. Crop and Livestock Rep. Serv., Sacramento, Calif. 18 p.
- CCLRS. 1977. California Grape Acreage. 1977. Calif. Crop and Livestock Rep. Serv., Sacramento, Calif.
- CCLRS. 1978. California Fruit and Nut Statistics. 1977-1978. Calif. Crop and Livestock Rep. Serv., Sacramento, Calif. 3 p.
- CCLRS. 1978a. Grapes, Raisins, and Wine, 1977, Production and Marketing. Calif. Crop and Livestock Rep. Serv., Sacramento, Calif.
- CCLRS. 1979. Fruit and Nut Statistics, 1977-1978. Calif. Crop and Livestock Rep. Serv., Sacramento, Calif.
- CCLRS. 1979a. California Grape Acreage, 1978. Calif. Crop and Livestock Rep. Serv., Sacramento, Calif.

- CCLRS. 1979b. Grapes, Raisins, and Wine, 1978 Production and Marketing. Calif. Crop and Livestock Rep. Serv., Sacramento, Calif.
- CCLRS. 1979c. California Grape Acreage, 1978. Calif. Crop and Livestock Rep. Serv., Sacramento, Calif.
- CDPH. 1970. Occupational Disease in California Attributed to Pesticides and Other Agricultural Chemicals. Calif. Dep. Publ. Health, Bureau of Occupational Health and Environ., Epidemiol., Berkeley, Calif. 30 p.
- Chappell, W. E. 1979. Personal Communication. Jan. 27. Va. Polytech. Inst., Blacksburg, Va.
- Chappell, W. E. 1979a. Personal Communication. Sept. Va. Polytech. Inst., Blacksburg, Va.
- Cheek, M. 1978. Personal Communication. Nov. 30. Farmersville, Tex.
- Chiarappa, L. 1959. Extracellular Oxidative Enzymes of Wood-Inhabiting Fungi Associated with the Heart Rot of Living Grapevines. Phytopathol. 49:578-583.
- Chiarappa, L. 1959a. Wood Decay of the Grapevine and Its Relationship with Black Measles Disease. Phytopathol. 49:510-519.
- Christensen, L. P. 1978. Personal Communication. Nov. 7. Univ. Calif., Fresno, Calif.
- Christensen, L. P., et al. 1976. Sample Costs to Produce Thompson Seedless for Raisins or Wine in the San Joaquin Valley. Spec. Publ. 3092. Div. Agric. Sci., Univ. Calif., Berkeley, Calif.
- Christensen, L. P., et al. 1978. Sample Costs to Establish a Vineyard of Thompson Seedless for Raisins or Wine in the San Joaquin Valley. Spec. Publ. 3091. Div. Agric. Sci., Univ. Calif., Berkeley, Calif.
- Christensen, L. P., et al. 1978a. Sample Costs to Establish a Vineyard of Thompson Seedless for Table Use in the San Joaquin Valley. Spec. Publ. 3093, Div. Agric. Sci., Univ. Calif., Berkeley, Calif.
- Christensen, L. P., et al. 1978b. Sample Costs to Produce Thompson Seedless for Table Use in the San Joaquin Valley. Spec. Publ. 3094, Div. Agric. Sci., Univ. Calif., Berkeley, Calif.
- Christensen, L. P., et al. 1978c. Sample Costs to Establish a Vineyard of Emperor Grapes in the San Joaquin Valley. Spec. Publ. 3089, Div. Agric. Sci., Univ. Calif., Berkeley, Calif.
- Christensen, L. P., et al. 1978d. Sample Costs to Produce Emperor Grapes in the San Joaquin Valley. Spec. Publ. 3090, Div. Agric. Sci., Univ. Calif., Berkeley, Calif.
- Christensen, L. P., et al. 1978e. Sample Costs to Establish a Wine Variety Vineyard in the San Joaquin Valley. Spec. Publ. 3095, Div. Agric. Sci., Univ. Calif., Berkeley, Calif.

- Christensen, L. P., et al. 1978f. Sample Costs to Produce Wine Varieties in the San Joaquin Valley. Spec. Publ. 3096, Div. Agric. Sci., Univ. Calif., Berkeley, Calif.
- Christensen, L. P., et al. 1978g. Demand Relationships for California Tree Fruits, Grapes, and Nuts: A Review of Past Studies. Spec. Publ. 3247. Div. Agric. Sci., Univ. of Calif., Berkeley, Calif.
- Citrus Admin. Comm. 1978. Weekly Statistical Bulletin, 1977-78 Season, Lakeland, Fla.
- Citrus Admin. Comm. 1978a. Annual Statistical Records, 1977-78 Season, Lakeland, Fla.
- Citrus Admin. Comm. 1979. Weekly Statistical Bulletin, 1978-79 Season, Lakeland, Fla.
- Citrus Admin. Comm. 1979a. Annual Statistical Records, 1978-79 Season, Lakeland, Fla.
- Clack, R. M. 1978. Personal Communication. Nov. 30. Caddo Mills, Tex.
- Clinard, D. 1978. Personal Communication. Dec. 1. Royse City, Tex.
- Clinard, G. 1978. Personal Communication. Nov. 30. Royse City, Tex.
- Coad, B. R., and J. P. Cassidy. 1920. Cotton Boll Weevil Control by the Use of Poison. U.S. Dept. Agric. Bull. 875. Wash., D.C. 31 p.
- Coates, G. 1979. Personal Communication. Dept. of Pathol. and Weed Sci., Miss. State Univ., State College, Miss.
- Colorado. 1977. Insect Control Handbook for Colorado. Coop. Ext. Serv., Colorado State Univ. Fort Collins, Colo.
- Colwell, R. R. 1977. Microbial Degradation of Petroleum in the Marine Environment. Rep. No. UM/ONR-4, Contract No. N00014-75-C-0340. Univ. of Md., Dept. of Microbiol., College Park, Md.
- Combs, R. 1979. Personal Communication. Entomology Dept., Miss. State Univ., State College, Miss.
- Compton, C. C. 1976. Petition Proposing Tolerances for Calcium Arsenate in or on Grapefruit Production. EPA Pestic. Petition 6E1737 and Food Additive Petition 6H5153. (Jan. 23).
- Connecticut. 1976. Control of Flies, Mosquitoes and Lice on Horses. Coop. Ext. Serv., Univ. Conn., Storrs, Conn.
- Connecticut. 1976a. Poultry Lice and Mite Control. Coop. Ext. Serv., Univ. Conn., Storrs, Conn.
- Cooper, A. L. 1978. Personal Communication. Dec. 1. Greenville, Tex.
- Corbin, R. 1978. Personal Communication. Aug. 30. Texas Agric. Ext. Serv. Texas A&M. Waxahachie, Tex.

- Corner, E.D.S., R. P. Harris, C. C. Kilvington, and S.C.M. O'Hara. 1976. Petroleum Compounds in the Marine Food Web: Short-Term Experiments on the Fate of Naphthalene in Calamus. J. Marine Biol. Assoc. 56:121-133.
- Cotton Council International. National Cotton Council. 1978. U.S. Cotton Varieties-1977. Memphis, Tenn.
- Cotton Grower. 1980. Vol. 16, No. 1, Meister Publ. Co. Willoughby, Ohio. 41 p.
- Cotton Incorporated. 1973. Guidelines for Using the Cotton Module Builder System for Handling and Storing Seed Cotton. Res. and Ext. Cotton Module Builder Workshop. Greenville, Miss.
- Crabtree, D. G. 1961. Review of Current Vertebrate Pesticides. Proc. Vertebrate Pest Control Conf., Sacramento, Calif. p. 327-362.
- Crowell, H. H. 1967. Slug and Snail Control with Experimental Poison Baits. J. Econ. Entomol. 60:1048-1050.
- Cruz, I.S.P., and L. Leiderman. 1974. Trakephon- Novo Desfolhante Para Algodoeiro. O. Biologico XL, p. 290-295.
- Culver, H. 1980. Personal Communication. Jan. 25. Pennwalt Corporation, Bryan, Tex.
- Cummings, R. W. 1979. Personal Communication. Aug. 31. J. & L. Adikes Co., Jamaica, N.Y.
- Cummings, W. 1979a. Personal Communication. Sept. 20. U.S. Environ. Prot. Agency. Wash., D.C.
- Cunningham, C. 1980. Personal Communication. June 27. USDA/ASCS., Wash., D.C.
- Daly, J. M. 1980. Personal Communication. Apr. 4. Daly Ranch, Carpinteria, Calif.
- Daniel, W. H. 1980. Personal Communication. Aug. 26. Purdue Univ., West Lafayette, Ind.
- Daniel, W. H., and R. P. Freeborg. 1970. The Arsenical Approach to Poa annua Control. Midwest Turf Conf. Proc. p. 30-32.
- Davis, W. 1980. Personal Communication. Golden Green, Ardmore, Okla.
- Dean-Raymond, D., and R. R. Bartha. 1975. Biodegradation of Some Polynuclear Aromatic Petroleum Components by Marine Bacteria. Tech. Rep. No. 5, Office of Naval Res. (N0014-67-0115-005). Wash., D.C.
- Deszyck, E. J., H. J. Reitz, and J. W. Sites. 1954. Basic Copper Arsenate--A New Material for Grapefruit Maturity Sprays. Citrus Mag. 16(7):15-17.
- Deszyck, E. J., and S. V. Ting. 1958. Seasonal Changes in Acid Content of Ruby Red Grapefruit as Affected by Lead Arsenate Sprays. Proc. Am. Soc. Hortic. Sci. 72:304-308.
- Devine, K. 1979. Personal Communication. Sept. 14. U.S. Environ. Prot. Agency, Wash., D.C.

- Devine, K. 1979a. Personal Communication. Sept. 27. U.S. Environ. Prot. Agency, Wash., D.C.
- Doane Agricultural Serv., Inc. 1978. USDA Citrus Study--1977. Econ. Res. Serv. U.S. Dept. Agric. Contract 12-17-01-1-2202.
- Doggett, D. 1978. Personal Communication. Aug. 18. Texas Agric. Ext. Serv. Texas A&M. Marlin, Tex.
- Dow Chemical. 1979. Personal Communication. Sept. 14. Dow Chemical Co. USA, Midland, Mich.
- Drisko, R. W., and T. B. O'Neill. 1966. Microbiological Metabolism of Creosote. For. Prod. J. 16(7):31-34.
- Durrenberger, C. J. 1975. Particulate and Arsenic Emissions of Texas Cotton Gins Processing Machine Stripped Cotton. Texas Air Control Board. Austin, Tex.
- Eickhoff, B. H., H. Willcutt, and L. Warner. 1977. Effect of Module Storage on Lint and Seed Quality. Presented at the Rolling Plains Cotton Module Building Demonstration by Cotton Inc. Raleigh, N.C.
- Elliott, J. N. 1979. Personal Communication. Apr. 13. Los Angeles Chem. Co., Southgate, Calif.
- Elrich, C. 1979. Personal Communication. Nov. 10. Pinuba, Calif.
- EPA. 1972. Arsenical Pesticides, Man, and the Environment. OPP-U.S. Environ. Prot. Agency, Wash., D.C.
- EPA. 1972a. Internal Analysis of Arsenicals unpublished, Economical Analysis Branch, OPP-U.S. Environ. Prot. Agency, Wash., D.C.
- EPA. 1976b. Arsenical Pesticides. Internal Review. U.S. Environ. Prot. Agency, Wash., D.C.
- EPA. 1976c. Site/Pest/Chemical Microfiche File. Oct. Office of Pesticide Programs, U.S. Environ. Prot. Agency, Wash., D.C.
- EPA. 1977. Technical Review of the Best Available Technology, Best Demonstrated Technology, and Pretreatment Technology for the Timber Products Processing Point Source Category. Draft Contractor's Report, Project No. 75-054. U.S. Environ. Prot. Agency, Wash., D.C.
- EPA. 1977a. Use Pattern Data Base for Sodium Arsenite Herbicides. Compiled by G. W. Keitt, Jr., and W. F. Cummings. CED-OPP-U.S. Environ. Prot. Agency, Wash., D.C.
- EPA. 1978a. Suspended and Canceled Pesticides. May. Officer of Public Awareness. U.S. Environ. Prot. Agency, Wash., D.C.
- EPA. 1979. Pesticide Product Information on Microfiche. OPTS, U.S. Environ. Prot. Agency, Wash., D.C.
- EPA. 1979a. Pesticide Price Files. Econ. Anal. Branch. Benefits and Field Studies Div. Opp. U.S. Environ. Prot. Agency, Wash., D.C.

- EPA/USDA. 1978. Preliminary Benefit Analysis of Lindane. June. U.S. Environ. Prot. Agency and U.S. Dept. Agric., Wash., D.C.
- Escritt, J. R. 1958. Calcium Arsenate for Earthworm Control. J. Sports Turf Res. Inst. 9(41):28-34.
- Facteau, T. 1979. Personal Communication. Nov. 28. Oregon Exp. Stn., Hood River, Oreg.
- Facteau, T. 1979a. Personal Communication. Dec. 5. Oregon Exp. Stn., Hood River, Oreg.
- Fairchild, G. F., and D. S. Tilley. 1979. The Economic Importance of Lead Arsenate to the Florida Grapefruit Industry, Jan. 26. Paper Prepared at the Fla. Dept. Citrus, Food and Resource Economics Dept., Univ. of Fla., Gainesville, Fla.
- FCIC. 1979. Unpublished Data Provided by the Federal Crop Insurance Corporation. Dec. 11. Kansas City, Mo.
- FDA. 1964. Cottonseed, Cottonseed Flour; Arsenic Limitation. Fed. Reg., Sept. 25, p. 13319.
- FEDS Budgets. 1977. Okla. State Univ., Stillwater, Okla.
- Federal Register. 1978. EPA, Position Document 1, Wood Preservative Pesticides. Books 1 and 2. 43(202):48153-48617 U.S. Gov. Print. Off., Wash., D.C.
- FIFRA. Docket No. 341. 1976. Respondents Brief, Proposed Findings and Conclusions. U.S. Environ. Prot. Agency, Off. General Counsel. W. A. White, Wash., D.C.
- Ficklin, S. H. 1979. Personal Communication. Nov. 20. Madera, Calif.
- Filty, B. 1978. Personal Communication. Celeste, Tex.
- Fisher, F. 1980. Personal Communication. Jan. 19. Fisher and Sons Co., Inc., Malvern, Pa.
- Florida. 1976. Florida Insect Control Guide: 1976. Inst. Food and Agric. Sci. Univ. Fla., Gainesville, Fla.
- Florida Agric. Statistics. 1975. Citrus Summary for 1975, Fla. Crop and Livestock Rep. Serv., Fla. Dept. of Agric. and Consumer Services, Orlando, Fla.
- Florida Agric. Statistics. 1978. Citrus Summary for 1978, Fla. Crop and Livestock Rep. Serv., Fla. Dept. of Agric. and Consumer Services, Orlando, Fla.
- Florida Citrus Code of 1949. Chapter 601, Florida Statutes. Lakeland, Fla.
- Florida Citrus Mutual. 1972. Annual Statistical Report, 1971-72, Lakeland, Fla.
- Florida Citrus Mutual. 1973. Annual Statistical Report, 1972-73, Lakeland, Fla.
- Florida Citrus Mutual. 1974. Annual Statistical Report, 1973-74, Lakeland, Fla.
- Florida Citrus Mutual. 1975. Annual Statistical Report, 1974-75, Lakeland, Fla.

- Florida Citrus Mutual. 1976. Annual Statistical Report, 1975-76, Lakeland, Fla.
- Florida Citrus Mutual. 1977. Annual Statistical Report, 1976-77, Lakeland, Fla.
- Florida Citrus Mutual. 1978. Annual Statistical Report, 1977-78, Lakeland, Fla.
- Florida Citrus Mutual. 1979. Annual Statistical Report, 1978-79, Lakeland, Fla.
- Florida Crop and Livestock Rep. Serv. 1971-79. Florida Citrus: Monthly Crop Forecast, Oct. 1971 through Sept. 1979, Orlando, Fla.
- Florida. Dept. of Agric. and Consumer Services. 1975-1976. Annual Report of the Div. Fruit and Vegetable Insp. Tallahassee, Fla. 90 p.
- Florida. Dept. of Agric. and Consumer Services. 1978. Commercial Citrus Tree Inventory--Preliminary Report. Div. Mktg. Plant. Ind. Tallahassee, Fla. 8 p.
- Freeborg, R. P. 1971. Arsenic Concentrations Required for Poa annua Control as Determined by Soil Tests. Ph. D. Thesis, Purdue Univ., W. Lafayette, Ind. 137 p.
- Fuller, W. H. 1977. Movement of Selected Metals, Asbestos, and Cyanide in Soil: Applications to Waste Disposal Problems. Municipal Environ. Res. Lab., U.S. Environ. Prot. Agency, Cincinnati, Ohio, EPA 600/2-77-020.
- Gallion, J. 1979. Personal Communication. Okla. Air Qual. Serv. Board, Oklahoma City, Okla.
- Gamboni, W. J. 1979. Personal Communication. Sept. 30. W. J. Gamboni Co., Delano, Calif.
- Gardner, B. R., and J. L. Troutman. 1975. Use of Soil Sterilants to Defoliate and Terminate Growth of Irrigated Cotton. Agron. J. 67:95-97.
- Garoyan, L., J. Brandt, and W. Kinney. 1975. California's Grape Industry. Some Economic Considerations. Bull. 1875, Div. Agric. Sci., Univ. Calif., Davis, Calif. 36 p.
- Gaskin, J. 1974. Disinfectants and Disinfection. Veterinary Medicine Fact Sheet VM-3, Florida Coop. Ext. Serv., Univ. Fla., Gainesville, Fla. 3 p.
- Geesleman. 1979. Personal Communication. Aug. 15. Reston Golf Course, Reston, Va.
- Georgia. 1974. Control External Parasites and Horse Flies Around Poultry Operations. College of Agric. Univ. Ga., Athens, Ga.
- Getzin, L. W., and S. G. Cole. 1964. Evaluation of Potential Molluscicides for Slug Control. Wash. Agric. Exp. Stn. Bull. 658:1-9.
- Gibb, H. 1979. Personal Communication. May 7. U.S. Environ. Prot. Agency, Wash., D.C.
- Gray, P.H.H., and H. G. Thornton. 1928. Soil Bacteria That Decompose Certain Aromatic Compounds. Zentralbl. Bakteriell. Parasitenkd. Abt. 2 73:74-96.
- Green, C. W. 1978. Personal Communication. Texas Agric. Ext. Serv. Texas A&M. Midland, Tex.

- Green, R. 1978. Personal Communication. Dec. 1. Caddo Mills, Tex.
- Greenway, B. L. 1978. Personal Communication. Nov. 21. Texas Agric. Ext. Serv. Texas A&M. Greenville, Tex.
- Griffith, W. B. 1978. Personal Communication. Aug. 14. Texas Agric. Ext. Serv. Texas A&M. Big Spring, Tex.
- Griggs, J. 1978. Personal Communication. Nov. 30. Caddo Mills, Tex.
- Growers Admin. Comm. 1972. Weekly Statistical Bulletin, 1971-72 Season, Lakeland, Fla.
- Growers Admin. Comm. 1972a. Annual Statistical Records, 1971-72 Season, Lakeland, Fla.
- Growers Admin. Comm. 1973. Weekly Statistical Bulletin, 1972-73 Season, Lakeland, Fla.
- Growers Admin. Comm. 1973a. Annual Statistical Records, 1972-73 Season, Lakeland, Fla.
- Growers Admin. Comm. 1974. Weekly Statistical Bulletin, 1973-74 season, Lakeland, Fla.
- Growers Admin. Comm. 1974a. Annual Statistical Records, 1973-74 Season, Lakeland, Fla.
- Growers Admin. Comm. 1975. Weekly Statistical Bulletin, 1974-75 Season, Lakeland, Fla.
- Growers Admin. Comm. 1975a. Annual Statistical Records, 1974-75 Season, Lakeland, Fla.
- Growers Admin. Comm. 1976. Weekly Statistical Bulletin, 1975-76 Season, Lakeland, Fla.
- Growers Admin. Comm. 1976a. Annual Statistical Records, 1975-76 Season, Lakeland, Fla.
- Growers Admin. Comm. 1977. Weekly Statistical Bulletin, 1976-77 Season, Lakeland, Fla.
- Growers Admin. Comm. 1977a. Annual Statistical Records, 1976-77 Season, Lakeland, Fla.
- Gustafson, C. D., and R. C. Rock. 1977. Orange Production Costs. Coop. Ext. Serv CP-212-3000. Univ. Calif., San Diego, Calif.
- Hale, T. J. 1979. Personal Communication. Oct. 23. Calif. Grape and Tree Fruit League, Fresno, Calif.
- Hall, J. R. 1980. Personal Communication. VPI and SU, Blacksburg, Va.
- Haney, B. 1978. Personal Communication. Oct. 18. Industrial Solvents, San Marcos, Tex.

- Harding, P. L., and D. F. Fisher. 1945. Seasonal Changes in Florida Grapefruit. U.S. Dept. Agric. Tech. Bull. 886. 46 p.
- Harrison, J.W.E., E. W. Packman, and D. D. Abbott. 1958. Acute Oral Toxicity and Chemical and Physical Properties of Arsenic Trioxides. Am. Med. Assoc. Arch. Ind. Health 17:118-123.
- Heneke, N. L. 1978. Personal Communication. Oct. 24. James Varley and Sons, Inc., St. Louis, Mo.
- Hepner, R. D. 1977. Investigations on the Leaching of Creosote and Creosote Degradation Products from Soil: Sand: Creosote Mixtures. Koppers Co., Pittsburgh, Pa.
- Hertzmark, D. 1974. Economic Impact of Restricting the Use of Lead Arsenate. Dec. 30. EPA/EAB, Wash., D.C.
- Hess, R. E. 1975. Arsenic Chemistry in Missouri Soils. Ph.D Diss., Univ. Mo., Columbia, Mo. (76-7501 Ann Arbor, Mich.).
- Hewitt, W. B. 1952. Some Responses of Grapevines to Sodium Arsenite Spray Applied for Black Measles Control. Phytopathol. 42:158-161.
- Hewitt, W. B. 1970. Personal Communication. Dec. 10. Univ. Calif., Davis, Calif.
- Hewitt, W. B. 1971. Sodium Arsenite in Control of Diseases of Grapevines. Prepared Statement. Univ. Calif., Parlier, Calif.
- Hewitt, W. B. 1978. Personal Communication. Nov. 12. Univ. Calif., Davis, Calif.
- Hewitt, W. B., and F. L. Jensen. 1965. Black Measles of Grapevine. Bull. Univ. Calif. Agric. Ext. Serv. Davis, Calif. 2 p.
- Hidalgo, R. 1979. Personal Communication. Dept. Vet. Med., Miss. State Univ., State College, Miss.
- Hildreth, R. J., and R. B. Orton. 1963. Freeze Probabilities in Texas. MP 1967. Mag. Texas Agric. Exp. Stn. College Station, Tex.
- Hillebrecht, B. 1980. Personal Communication. Apr. 8. Escondido, Calif.
- Hoermann, H. 1978. Personal Communication. Texas Agric. Ext. Serv. Texas A&M. Refugio, Tex.
- Hopphan, C. G. 1980. Personal Communication. Jan. 21. Aurora Country Club, Aurora, Ill.
- Howell, D. 1979. Personal Communication. Aug. 15. Athens Country Club, Athens, Ga.
- Howitt, A. 1979. Personal Communication. Apr. Michigan State Univ., East Lansing, Mich.
- Illinois. 1976. 1977 Insect, Pest Management Guide: Home, Yard and Garden, Circular 900. College of Agric. Coop. Ext. Serv. Univ. Ill., Urbana-Champaign, Ill.

- Illinois. 1976a. 1977 Insect Pest Management guide: Livestock and Livestock Barns. College of Agric. Coop. Ext. Univ. Ill., Urbana-Champaign, Ill.
- Indiana. 1975. Indiana 1975 Fruit Spray Schedule. Coop. Ext. Serv., Purdue Univ., West Lafayette, Ind.
- Indiana. 1976. Entomology: E-Series Publication. Coop. Ext. Serv., Purdue Univ., West Lafayette, Ind.
- Indyk. 1979. Personal Communication. Aug. 14. Rutgers Univ., New Brunswick, N.J.
- Iowa. 1978. Summary of Iowa Insect Pest Control: Recommendations for 1978. Coop. Ext. Serv., Iowa State Univ., Ames, Iowa.
- Jacobs, S. E. 1931. The Influence of Antiseptic on the Bacterial and Protozoan Population of Greenhouse Soils. Ann. Appl. Biol. 18(1):98-136.
- Jagschitz, J. A. 1979. Personal Communication. Aug. 16. Univ. R.I., Providence, R.I.
- Jakovich, J. 1979. Personal Communication. Delano, Calif.
- Jensen, F. L. 1979. Personal Communication. Oct. 12. Univ. Calif., Parlier, Calif.
- Jensen, F. L. 1979a. Personal Communication. Dec. Univ. Calif., Parlier, Calif.
- Johnson, R. E., R. G. Curley, A. George, O. D. McCutcheon, V. T. Walhood, C. R. Brooks, and P. Young. 1974. Yield Potential of Short-Season Cotton in Narrow Rows. Calif. Agric. Nov. p. 6-8.
- Johnston, H. R., V. K. Smith, and R. H. Beal. 1972. Subterranean Termites, Their Prevention and Control in Buildings. U.S. Dept. Agric. Home and Garden Bull. 64. 30 p.
- Jones, A. C. 1978. Personal Communication. Hickson and Welsh Ltd., West Yorkshire, England.
- Judge, F. D. 1969. Preliminary Screening of Candidate Molluscicides. J. Econ. Entomol. 62:193-197.
- Judge, F. D., and R. J. Kuhr. 1972. Laboratory and Field Screening of Granular Formulations of Candidate Molluscicides. J. Econ. Entomol. 65:242-245.
- Kansas. 1974. Livestock Insect Control Recommendations. Coop. Ext. Serv., Kans. State Univ., Manhattan, Kans.
- Karaffa, G. 1979. Personal Communication. Gustafson Co., Dallas, Tex.
- Kasimatis, A. N. 1979. Personal Communication. Apr. 4. Univ. Calif., Davis, Calif.
- Keitt, G. W. 1979. Personal Communication. Aug. 1. U.S. Environ. Prot. Agency, Wash., D.C.

- Kelejain, H. H., and W. E. Oats. 1974. Introduction to Econometrics: Principles and Applications. Harper and Rowe Publ. Co., New York, N.Y.
- Kelly, V. L. 1978. Personal Communication. Nov. 30. Caddo Mills, Tex.
- Kennedy, J. 1979. Personal Communication. Oct. 10. U.S. Environ. Prot. Agency, Wash., D.C.
- Kentucky. 1976. 1977 Insect Management Recommendations for Field Crops and Livestock. College of Agric. Coop. Ext. Univ. Ky., Lexington, Ky.
- Kerr, C. F. 1980. Personal Communication. Jan. 21. Mallinckrodt, Inc., St. Louis, Mo.
- Kerr, C. F., and W. H. Daniel. 1969. Poa annua Restrictions. Golf Course Super. 37 p.
- Kerr, C. F., and W. H. Daniel. 1969a. Program for the Gradual Removal of Poa annua from Cool Season Grasses. Rhodia Chem. Co. Newsletter. Boundbrook, N.J.
- Kiggins, E. M. 1979. Personal Communication. Rhodia Inc., Ashland, Ohio.
- Kilpatrick, J. 1979. Personal Communication. Apr. State Univ. of N.Y., Geneva, N.Y.
- Kirk, I. W., E. B. Hudspeth, and A. D. Brashears. 1972. Harvesting Performance of Horizontally Oriented Picker Drum on Storm Resistant Cotton Varieties. Texas Agric. Exp. Stn. MP 1030.
- Kissler, J. 1979. Deadarm Disease Reduces Tokay Grape Crops. Calif.-Ariz. Farm Press 1:6. (Feb. 13).
- Kiyohara, H., K. Nagao, and R. Nomi. 1976. Degradation of Phenanthrene Through -Phthalate by Aeromonas Sp. Agric. Biol. Chem. 40(6):1075-1082.
- Kleeman. 1979. Personal Communication. Aug. 14. Univ. Maryland. College Park, Md.
- Knapp, J. L. 1979. Florida Citrus Spray Guide. Fla. Coop. Ext. Serv. Circ. 393. Gainesville, Fla.
- Koepf, A. 1979. Personal Communication. Stanford Seed Co., Buffalo, N.Y.
- Koppitz, R. 1980. Personal Communication. Alva Golf and Country Club, Alva, Okla.
- Koss, G., and W. Koransky. 1978. Pentachlorophenol in Different Species of Vertebrates after Administration of Hexachlorobenzene and Pentachlorobenzene. In Pentachlorophenol, (R. K. Rao, ed.). Plenum Press, New York, N.Y. p. 131-140.
- Lange, W. H., Jr., and G. F. MacLeod. 1941. Metaldehyde and Calcium Arsenate in Slug and Snail Baits. J. Econ. Entomol. 34:321-322.
- Leavitt, G. Undated. Phomopsis Cane and Leaf Spot (Dead-Arm). Agric. Ext. Serv., Univ. Calif., Madera County, Calif. 3 p.

- Lee, R. F. 1975. Fate of Petroleum Hydrocarbons in Marine Zooplankton. In Conference on Prevention and Control of Oil Pollution Effects, Natl. Res. Council of Canada, Ottawa, Ont. p. 549-553.
- Lee, R. F., and J. W. Anderson. 1977. Fate and Effect of Naphthalenes: Controlled Ecosystem Pollution Experiments. *Bull. Marine Sci.* 27(1):127-134.
- Lee, R. F., W. S. Gardner, J. W. Anderson, J. W. Blaylock, and J. Barwell-Clarke. 1978. Fate of Polycyclic Aromatic Hydrocarbons in Controlled Ecosystem Enclosures. *Environ. Sci. Technol.* 12(7):832-837.
- Lee, R. F., and C. Ryan. 1976. Biodegradation of Petroleum Hydrocarbons by Marine Microbes. Aug. 17. *Proc. Third International Biodegradation Symp.*, Kingston, R.I. p. 119-125.
- Lee, R. F., C. Ryan, and M. L. Neuhauser. 1976. Fate of Petroleum Hydrocarbons Taken up from Food and Water by the Blue Crab Callinectes sapidus. *Marine Biol.* 37:363-370.
- Leibacher, E. 1980. Personal Communication. Feb. 28. Santa Ana, Calif.
- Linney, L. 1978. Personal Communication. Martin County Insect Control Assoc., Stanton, Tex.
- Livingston, A. M. 1978. Personal Communication. Oct. 18. Blue Spruce Co., Basking Ridge, N.J.
- London, F. 1978. Personal Communication. Dec. 1. Wolfe City, Tex.
- Longfield-Smith, L. 1935. Work of the Winter Haven Chemical Laboratory. *Annu. Rep. Fla. Dept. Agric.* Tallahassee, Fla. 90 p.
- Louisiana. 1976. 1976 Insect Control Guide. Coop. Ext. Serv., Louisiana State Univ., Baton Rouge, La.
- Loustalot, A. J., and R. Ferrer. 1950. The Effect of Some Environmental Factors on the Persistence of Sodium Pentachlorophenate in the Soil. *Proc. Am. Assoc. Hortic. Sci.* 56:294-298.
- Lovell, A. 1979. Various Crop Production Budgets Prepared for Blacklands Region. Texas A&M Univ., Bryan, Tex.
- Lovett, A. L., and A. B. Black. 1920. The Gray Garden Slug. *Oregon Agric. Exp. Stn. Bull.* 170:1-43.
- Lowrey, E. 1978. Personal Communication. Dec. 1. Wolfe City, Tex.
- Lowrey, J. 1978. Personal Communication. Dec. 3. Wolfe City, Tex.
- Lowrey, P. 1978. Personal Communication. Dec. 1. Wolfe City, Tex.
- Lucas, M. B., Jr. 1980. Personal Communication. Jan. 22. Piping Rock Club, Long Island, N.Y.

- Luttner, M. A., and L. A. Deluise. 1979. Economic Analysis of the Impact of a Lead Arsenate Cancellation on Florida Grapefruit. Sept. 14. Environ. Prot. Agency, Wash., D.C. Draft Report Prepared in Conjunction with J. Bratland, U.S. Dept. Agric., Wash., D.C.
- Mahe, B. 1978. Personal Communication. Farmers Coop Gin and Wholesale Co. Wolfe City, Tex.
- Malone, W. E. 1978. Personal Communication. Dec. 1. Wolfe City, Tex.
- Mann, W. 1979. Personal Communication. Research Forester, U.S. For. Serv., Pineville, La.
- Marshall, C. R. 1980. Personal Communication. Apr. 1. Santa Paula, Calif.
- Marshall, S. P., F. W. Hayward, and W. R. Meagher. 1963. Effects of Feeding Arsenic and Lead upon Their Secretion in Milk. J. Dairy Sci. 46:580-581.
- Maryland. 1978. Controlling Insects and Mites of Livestock and Other Animals, Bulletin 256. Coop. Ext. Serv., Univ. of Md., College Park, Md.
- Matthews, A. 1924. Partial Sterilization of Soil by Antiseptics. J. Agric. Sci. 14:1-57.
- Mattson, C. D. 1979. Personal Communication. Sept. 17. U.S. Environ. Prot. Agency, Wash., D.C.
- McCutchen, B. 1978. Personal Communication. Aug. 15. Texas Agric. Ext. Serv. Texas A&M. Cameron, Tex.
- McMillan, H. C. 1980. Personal Communication. Apr. 11. McMillan Bros. Citrus Ranch, Corona, Calif.
- McReynolds, G. B. 1980. Personal Communication. Apr. 2. Carpinteria, Calif.
- McWhorter, M. 1979. Personal Communication. Animal Sci. Dept., Texas A&M Univ., College Station, Tex.
- Mead, A. R. 1961. The Giant African Snail. Univ. Chicago Press, Chicago, Ill.
- Merck Index. 1968. An Encyclopedia of Chemicals and Drugs. (P. G. Stecher, ed.). Eighth Edition. Merck & Co., Rahway, N.J.
- Merlo, F. 1979. Personal Communication. Nov. 5. Sanger, Calif.
- Metcalf, C. I., and W. P. Flint. 1962. Destructive and Useful Insects. McGraw-Hill Book Co., New York, N.Y.
- Metzer, R. E., 1978. Annual Survey of County Agents and Texas Crop and Livestock Rep. Serv. Texas A&M, College Station, Tex.
- Metzer, R. E. 1979. Personal Communication. Oct. 31. Texas A&M Univ., College Station, Tex.
- Metzer, R. E. 1979a. Personal Communication. Nov. 27. Texas A&M Univ., College Station, Tex.

- Metzer, R. E., and J. Supak. 1975. Cotton Defoliation Guide. L-145. Texas Agric. Ext. Serv. Austin, Tex.
- Michigan. 1973. For Poultry Insect and Mite Control. Coop. Ext. Serv., Mich. State Univ., East Lansing, Mich.
- Michigan. 1975. Controlling Insects and Mites on Horses. Coop. Ext. Serv., Mich. State Univ., East Lansing, Mich.
- Miller, C. S. 1974. The Efficiency of Arsenic Acid in Cotton Desiccation. Weed Sci. 22:388-393.
- Miller, C. S. 1979. Personal Communication. Texas A&M Univ., College Station, Tex.
- Miller, C. S., and M. M. Aboul-Ela. 1965. The Absorption of Harvest-Aid Chemicals. Proc. Cotton Defoliation and Physiol. Conf. p. 93.
- Miller, C. S., and M. M. Aboul-Ela. 1969. Fate of Pentachlorophenol in Cotton. J. Agric. Food Chem. 17(6):1244-1246.
- Miller, C. S., and W. H. Aldred. 1976. Further Research with Stalk-Applied Desiccants. Proc. Beltwide Cotton Prod. Res. Conf. p. 49-52.
- Miller, C. S., and W. H. Aldred. 1977. Determination of the Efficiency of Stalk Application of Desiccants. Proc. Beltwide Cotton Prod. Res. Conf. p. 69-72.
- Miller, C. S., T. P. Brendel, and P. C. Koska. 1978. Search for a New Cotton Desiccant. Proc. Beltwide Cotton Res. Conf. p. 58-60.
- Miller, C. S., E. D. Cook, J. L. Hubbard, J. S. Newman, E. L. Thaxton, and L. H. Wilkes. 1968. Cotton Desiccation Practices and Experimental Results in Texas. Texas Agric. Exp. Stn. MP 903. Nov. College Station, Tex. p. 16.
- Miller, C. S., W. L. Hoover, and W. H. Culver. 1980. Exposure of Applicators to Arsenic Acid. Arch. Environ. Contam. Toxicol. 9:281-288.
- Miller, C. S., W. L. Hoover, and J. D. Price. 1975. Pesticide Residues in Cotton Gin Wastes. Texas Agric. Exp. Stn. MP 1184. p. 18.
- Miller, C. S., L. H. Wilkes, E. L. Thaxton, and J. L. Hubbard. 1971. Cotton Wilt-Harvest and Wiltant Defoliation Effectiveness in Texas. Texas Agric. Exp. Stn. MP 1010.
- Miller, D., and E. Mackery. 1979. Personal Communication. U.S. Dept. Agric. Animal and Plant Health Insp. Serv., Hyattsville, Md.
- Miller, R. L., I. P. Bassett, and W. W. Yothers. 1933. Effect of Lead Arsenate Insecticides on Orange Trees in Florida. U.S. Dept. Agric. Tech. Bull. 350. 20 p.
- Minnesota. 1975. Insecticide Suggestions to Control Household Insects in 1975. Ext. Bull. 389. Agric. Ext. Serv., Univ. Minn., St. Paul, Minn.
- Minnesota. 1975a. Insecticide Suggestions to Control Livestock and Poultry Pests in 1975. Ext. Bull. 390. Agric. Ext. Serv., Univ. Minn., St. Paul, Minn.

- Misra, S. G., and R. C. Tiwari. 1963. Arsenite--Arsenate Adsorption in Soils. Indian J. Appl. Chem. 26(4):117-121.
- Mississippi. 1974. Protect Hogs From External Parasites. Coop. Ext. Serv., Miss. State Univ., State College, Miss.
- Mississippi. 1974a. Livestock Parasite Control: Hogs. Coop. Ext. Serv., Miss. State Univ., State College, Miss.
- Mississippi. 1975. Parasite Control for Cats and Dogs. Coop. Ext. Serv., Miss. State Univ., State College, Miss.
- Mississippi. 1976. Control External Parasites of Poultry. Coop. Ext. Serv., Miss. State Univ., State College, Miss.
- Mississippi State University. 1979. Personal Communication with Personnel of the Seed Technology Lab., Miss. State Univ., State College, Miss.
- Missouri. 1976. 1976 Missouri Insect Control Recommendations. Columbia Ext. Div., Univ. of Missouri, Columbia, Mo.
- Mitchell, W. G. 1979. Personal Communication. Apr. 30. Landia Chemical Co., Lakeland, Fla.
- Mitchell, W. G. 1980. Personal Communication. Jan. 28. Landia Chemical Co. Lakeland, Fla.
- Moller, W. J., and M. A. Soll. Undated. Measles. Dept. Plant Pathology, Univ. Calif., Davis, Calif.
- Moller, W. J. 1979. Personal Communication. Aug. Univ. Calif., Davis, Calif.
- Montana. 1975. Materials for Insect Control in Montana. Bulletin 1109. Coop. Ext. Serv., Montana State Univ., Bozeman, Mont.
- Moulton, K. S. 1979. California Grapes: The Situation in 1979. Calif. Agric. 33(3):4-5.
- Mullins, J. A., and R. J. Goddard. 1973. Turnrow Storage of Seed Cotton in Tennessee. Tenn. Farm Home Sci. Apr., May, June. p. 8-10.
- Murray, J. 1979. Personal Communication. Aug. 14. Univ. Maryland, College Park, Md.
- Nagel, F. J. 1979a. Personal Communication. Oct. Chapman Chemical Co., Memphis, Tenn.
- Naples, P. 1979. Personal Communication. Aug. 14. Golf Course Superintendents Association.
- National Oceanic Atmos. Admin. 1968-78. Climatological Data: Annual Summary. National Climatic Center, Ashville, N.C.
- Nebraska. 1975. Insect Control Guide for Household and Pets. Coop. Ext. Serv., Univ. Nebr., Lincoln, Nebr.

- Nelson, K. E., W. B. Hewitt, and R. A. Break. 1949. Arsenite Spray Injury to Grape Canes Through Leaf Scars. *Phytopathol.* 39:71-76.
- New Jersey. 1976. Pesticides for New Jersey. Coop. Ext. Serv., Rutgers - the State Univ., New Brunswick, N.J.
- New Mexico. 1973. Home and Garden Insect Control Guide. Coop. Ext. Serv., New Mex. State Univ., Las Cruces, N. Mex.
- New Mexico. 1974. External Parasites of Horses and Their Control. Coop. Ext. Serv., New Mex. State Univ., Las Cruces, N. Mex.
- New Mexico. 1976. Poultry Insect Guide. Coop. Ext. Serv., New Mex. State Univ., Las Cruces, N. Mex.
- Niles, G. A., L. H. Harvey, and J. K. Walker. 1978. Cultural Control of the Boll Weevil. In *The Boll Weevil: Management Strategies*. Southern Coop. Serv. Bull. 228. Univ. of Ark., Fayetteville, Ark. p. 23-38.
- North Carolina. 1977. 1977 North Carolina Agricultural Chemical Manual. School of Agric. and Life Sci., N.C. State Univ., Raleigh, N.C.
- North Dakota. 1977. North Dakota Insect Guide Control for Safe Use of Pesticides. Coop. Ext. Serv., N. Dak. State Univ., Fargo, N. Dak.
- Ohio. 1977. Control of Insect and Mite Pests of Poultry. Coop. Ext. Serv., Ohio State Univ., Columbus, Ohio.
- Ohio. 1977a. 1977 Ohio Commercial Fruit Spray Guide. Coop. Ext. Serv., Ohio State Univ., Columbus, Ohio.
- Ohio. 1978. Pesticides for Household Pets, Bulletin 512. Coop. Ext. Serv., Ohio State Univ., Columbus, Ohio.
- Oklahoma. 1975. Extension Agents' Handbook of Insect, Plant Disease and Weed Control. Univ. Ext., Okla. State Univ., Stillwater, Okla.
- Oklahoma Crop and Livestock Rep. Serv. 1978. Oklahoma Cotton Statistic 1973-78. Oklahoma City, Okla.
- Oklahoma Dept. Agric. 1967-78. Okla. Agric. Statistics. Oklahoma City, Okla.
- O'Neill, T. B., R. W. Drisko, and H. Hochman. 1961. *Pseudomonas creosotensis* Sp., A Creosote-Tolerant Marine Bacterium. *Appl. Microbiol.* 9:472-474.
- Orazi, R. 1980. Personal Communication. Feb. 11. Hunt Valley Golf Club, Hunt Valley, Md.
- Orton, R. 1979. Personal Communication. Dec. 12. El Paso Weather Station. El Paso, Tex.
- OSHA. 1978. Occupational Exposure to Inorganic Arsenic. *Fed. Reg.* 43(88): 19584-19631.
- Oswalt, E. S. 1978. Personal Communication. (Sept. 7). Okla. State Univ., Stillwater, Okla.

- Packman, E. W., D. D. Abbott, and J.W.E. Harrison. 1961. The Acute Oral Toxicity in Rats of Several Diets--Arsenic Trioxide Mixtures. J. Agric. Food Chem. 9(4):271-272.
- Paetz, P. E. 1980. Personal Communication. Jan. 16. All Best Inc., Tulsa, Okla.
- Painter, W. 1979. Personal Communication. (May). Butler County Mushroom Farms, Inc., Worthington, Pa.
- Parnell, C. B. 1967. Cotton Module Building--Ginning Clinic. Summary of Proc. Ginning Clinic Held at Nueces County Memorial Agric. Center. Texas A&M Univ., College Station, Tex.
- Parvin, D. W. Jr., J. G. Hamill, and F. T. Cooke. 1979. Budgets for Major Crops: MAFES Research Highlights. Miss. State Univ. Mississippi State, Miss.
- Patton, T. 1979. Personal Communication. (May). Castle and Cooke Foods, Salem, Oreg.
- Pennsylvania. 1977. 1977 Pest Control Suggestions. College of Agric. Ext. Serv., Pa. State Univ., University Park, Pa.
- Pennsylvania. 1977a. 1977 Tree Fruit Production Guide. Coop. Ext. Serv., Pa. State Univ., University Park, Pa.
- Pennwalt. 1978. Privileged Communication of Arsenic Analyses. Bryan, Tex.
- Pennwalt. 1979. Response of Pennwalt Corporation to the Notice of Rebuttable Presumption Against Registration and Continued Registration of Pesticide Products Containing Inorganic Arsenic (FRL 984-3; OPP 30000/291). Feb. 12. King of Prussia, Pa.
- Percival, B. R. 1978. Personal Communication. Aug. 30. Texas Agric. Ext. Serv. Texas A&M. Crockett, Tex.
- Peters, J. A., and T. R. Blackwood. 1977. Source assessment: Defoliation of Cotton--State of the Art. U.S. Environ. Prot. Agency EPA-600/2-77-107g. Wash., D.C.
- Peters, M. 1979. Personal Communication. (May 1). Texas Air Control Board. Austin, Tex.
- Pickering, S. U. 1907. Note on the Arsenates of Lead and Calcium. J. Chem. Soc. 91:307-14.
- Pomatto, A. M. 1980. Personal Communication. Apr. 1. Goleta, Calif.
- Pressey, E. 1980. Personal Communication. Apr. 5. Vista, Calif.
- Price, E. A. 1978. Personal Communication. Texas Cotton Ginners Assoc., Dallas, Tex.
- Price, J. A. 1978. Personal Communication. Hickson's Timber Products Ltd. West Yorkshire, England.
- Puckett, A. Z. 1978. Personal Communication. Dec. 1. Greenville, Tex.

- Quisenberry, J. E. 1979. Personal Communication. Dec. 6. Lubbock Res. Stn. Lubbock, Tex.
- Rahill, G. W. 1980. Personal Communication. Apr. 8. Coronado, Calif.
- Rak, J. 1976. Leaching of Toxic Elements from Spruce Treated with Ammoniacal Solutions of Copper-Zinc-Arsenic Preservatives. Wood Sci. Technol. 10:47-56.
- Rambo, G. W., 1979. Personal Communication. Jan. 30. Natl. Pest Cont. Assoc., Vienna, Va.
- Rao, P., and R. L. Miller. 1971. Applied Econometricx. Wadsworth Publishing Co., Inc., Belmont, Calif.
- Ray, L. L., and E. B. Minton. 1973. Effects of Field Weathering on Cotton Lint Yield, Seed Quality and Fiber Quality. Oct. Texas Agric. Exp. Stn. MP 1118. College Station, Tex.
- Redeleff, R. D. 1964. Inorganic Compounds, Arsenic. Vet. Toxicol. 5:314
- Reeves, D. 1978. Personal Communication. Aug. 8. Texas Agric. Ext. Serv., Texas A&M. Wellington, Tex.
- Reimer, J. E. 1980. Personal Communication. Apr. 3. J. E. Reimers & Sons, Woodlake, Calif.
- Reue, D. E. 1978. Personal Communication. Aug. 18. Texas Agric. Ext. Serv. Texas A&M. Caldwell, Tex.
- Rhode Island. 1974. Pest Facts: Dog Tick. Coop. Ext. Serv., Univ. of R.I., Kingston, R.I.
- Rhode Island. 1974a. 1974b. Pest Facts: Fleas, No. 10. Coop. Ext. Serv., Univ. of R.I., Kingston, R.I.
- Richardson, C. W., J. D. Price, and E. Burnett. 1978. Arsenic Concentrations in Surface Runoff from Small Watersheds in Texas. J. Environ. Qual. 7:189-192.
- Riepma, S. F. 1978. Personal Communication. Dec. Natl. Assoc. Margarine Manuf., Wash., D.C.
- Ritehoven, J. 1980. Product Label No. 10659-53. Occidental Chem. Co., Houston, Tex.
- Roberts, J. O. 1980. Personal Communication. President, Senoret Chemical Co., Kirkwood, Mo.
- Roberts, W., Jr. 1978. Personal Communication. Aug. 22. Texas Agric. Ext. Serv. Texas A&M. Kaufman, Tex.
- Ruth, W. E. 1978. Personal Communication. Dec. 1. Texas Agric. Ext. Serv. Texas A&M, Greenville, Tex.
- Sears, G. 1978. Personal Communication. Aug. 14. Texas Agric. Ext. Serv. Texas A&M. Austin, Tex.

- Selby, S. M. 1967. Amortization Factors--Standard Mathematical Tables, 15th Ed. The Chemical Rubber Co. p. 610.
- Skogley, C. R. 1979. Personal Communication. Aug. 14. Univ. of R.I., Providence, R.I.
- Smith, J. B. 1908. Arsenate of Lime. Rep. New Jersey State Entmol. p. 476.
- Smith, T. M. 1978. Personal Communication. Dec. 15. Hill-Smith Termite Control, Inc. Nashville, Tenn.
- Smith, V. K. 1979. Personal Communication. Jan. 12. For. Prod. Insect Lab., U.S. For. Serv., Gulfport, Miss.
- Soll, M. A. 1978. Personal Communication. (Oct. 26). Univ. Calif., Davis, Calif.
- Sorenson, J. W., and L. H. Wilkes. 1973. Seed Quality and Moisture Relationships in Harvesting and Storing Seed Cotton. Cotton Inc., Raleigh, N.C.
- Soule, J., W. Grierson, and J. G. Blair. 1967. Quality Tests For Citrus Fruits. Fla. Agric. Ext. Serv. Circ. 315. 28 p.
- South Carolina. 1979. 1979 Agricultural Chemicals Handbook. Coop. Ext. Serv., Clemson Univ., Clemson, S.C.
- South Dakota. 1976. South Dakota Insecticide Recommendations. Coop. Ext. Serv., S. Dak. State Univ., Brookings, S. Dak.
- Southwest Farm Press. 1979. Nov. 15. Clarksdale, Miss.
- Stapp, R. 1979. Personal Communication. U.S. Environ. Prot. Agency, Wash., D.C.
- Stasse, H. L. 1964. A Study of Creosote Treatment of Seasoned and Green Southern Pine Poles. 9. Effect of Variables on Vapor Loss and Movement of Oil. Proc. Am. Wood-Pres. Assoc. 60:109-128.
- Stephens, H. 1979. Personal Communication. Jan. 23. Pacific Coast Resources Corp., Los Angeles, Calif.
- Stevning, D. A. 1980. Personal Communication. Apr. 19. L.V.W. Brown Estate. Riverside, Calif.
- Strawinsky, R. J., and R. W. Stone. 1940. The Utilization of Hydrocarbons by Bacteria. J. Bacteriol. 40:461-470.
- Supak, J. R. 1978. Personal Communication. Aug. 28. Texas Agric. Ext. Serv. Texas A&M. Lubbock, Tex.
- Supak, J. R. 1978a. Personal Communication. Nov. 14. Texas Agric. Ext. Serv. Texas A&M. Lubbock, Tex.
- Supak, J. 1978b. Personal Communication. Lubbock, Tex.
- Supak, J., and R. Metzger. Undated. Keys to Profitable Cotton Production in the High Plains. MP 1311. Texas Agric. Ext. Serv. College Station, Tex.

- Survey of Manufacturers. 1979. Informal Survey of Pesticide Manufacturers by the USDA/States/EPA Assessment Team.
- Suta, B. E. 1978. Human Exposures to Atmospheric Arsenic. Final Report Cress Rep. No. 50, U.S. Environ. Prot. Agency. 109 p. 68-01-4314 and 68-02-2835.
- Swanson, F. et al. 1978. Sample Costs to Produce Thompson Seedless for Raisins or Wine in the San Joaquin Valley. Spec. Publ. 3092, Div. Agric. Sci., Univ. Calif., Berkeley, Calif.
- Swift, J. D. 1978. Personal Communication. Aug. 7. Texas Agric. Ext. Serv. Texas A&M. Eldorado, Tex.
- Tattersfield, F. 1927. The Decomposition of Naphthalene in the Soil and the Effect Upon its Insecticidal Action. Ann. Appl. Biol. 15(1):57-80.
- Tausson, W. O. 1929. The Oxidation of Benzene Hydrocarbons by Bacteria. Plant 7:735-757.
- Taylor, J. J. 1933. Enforcement of the Arsenical Spray Law. Quart. Bull. Fla. Dept. Agric. 42(2):1-55.
- Tennessee. 1971. Effective, Economical and Safe Control Measures for Household Pests. Agric. Ext. Serv., Univ. of Tenn., Knoxville, Tenn.
- Tennessee. 1973. Pest Control for Horses, Sheep and Hogs. Agric. Ext. Serv., Univ. of Tenn., Knoxville, Tenn.
- Tennessee. 1975. You Can Control Household Pets. Agric. Ext. Serv., Univ. of Tenn., Knoxville, Tenn.
- Tennessee. 1977. 1977 Fruit Spray Schedules. Agric. Ext. Serv., Univ. of Tenn., Knoxville, Tenn.
- Texas. 1972. The New Screwworm Threat. Texas Agric. Ext. Serv., Texas A&M Univ., College Station, Tex.
- Texas. 1975. Suggestions for Controlling External Parasites of Livestock and Poultry. Texas Agric. Ext. Serv., Texas A&M Univ., College Station, Tex.
- Texas. 1979. External Parasite Control on Dogs, Cats and Birds. Texas Agric. Ext. Serv., Texas A&M Univ., College Station, Tex.
- Texas Crop and Livestock Rep. Serv. 1968-78. Texas Field Crops Statistics. Austin, Tex.
- Texas Crop and Livestock Rep. Serv. 1968-78a. Texas Cotton Statistics. Austin, Tex.
- Thomson, W. T. 1977. Agricultural Chemicals - Book I. Insecticides, Acaracides, and Ovicides. 1977 Revision. Thomson Publ., Fresno, Calif. 236 p.
- Thomson, W. T. 1977a. Agricultural Chemicals - Book II. Herbicides. 1977 Revision. Thomson Publ., Fresno, Calif. 264 p.

- Thomson, W. T. 1978. Agricultural Chemicals - Book IV. Fungicides. 1978 Revision. Thomson Publ., Fresno, Calif. 174 p.
- Thornton, M., and K. Thornton. 1978. Personal Communication. Dec. 1. Wolfe City, Tex.
- Tippit, O. J. 1971. Cotton Varieties for Stripper Harvesting in Central Texas. Texas Agric. Exp. Stn. Prog. Rep. 2223.
- Tracor Jitco Inc. 1979. Pesticide Chemical Use Pattern Profile for Strychnine. Draft, May 9. Benefits Field Studies Div. OPP U.S. Environ. Prot. Agency, Wash., D.C.
- Traxler, R. W. 1973. Petroleum Degradation in Low Temperature Marine Estuarine Environments. Rep. No. 98-01-4062-4. Univ. of Rhode Island, Kingston, R.I.
- USDA. 1965. Mechanized Harvesting of Cotton. South. Coop. Serv. Bull. No. 100. U.S. Dept. Agric., Wash., D.C. p. 35-37.
- USDA. 1974b. Guidelines for the Use of Insecticides to Control Insects Affecting Crops, Livestock, Households, Stored Products, Forest and Forest Products. Feb. U.S. Dept. Agric., Wash., D.C.
- USDA. 1974-79. Charges for Ginning Cotton, Cost of Selected Services Incident to Marketing and Related Information, 1978-79 Season. July. Wash., D.C.
- USDA. 1976. Controlling Household Pests, Home and Garden Bulletin No. 96. Mar. U.S. Dept. Agric., Wash., D.C.
- USDA. 1976a. Gypsy Moth and Browntail Moth-Regulatory. Aug. 3. Publ. #805-04,2110. Animal and Plant Health Inspection Service, Plant Protection and Quarantine Programs. U.S. Dept. Agric.
- USDA. 1978. Agricultural Statistics 1978, ESCS, U.S. Dept. Agric., Wash., D.C.
- USDA. 1978a. 1978 Citrus Pesticide Usage Survey. ESCS, U.S. Dept. Agric., Wash., D.C.
- USDA. 1979. ASCS Commodity Fact Sheets: 1979 Upland Cotton. Mar. Wash., D.C.
- USDA. 1979a. Statistics on Cotton and Related Data, 1960-78. Statistical Bulletin No. 617. Mar. Wash., D.C.
- USDA. 1979b. Premiums and Discounts for Grade and Staple Length of 1979-Crop American Upland Cotton. USDA/ASCS. Wash., D.C.
- USDA. 1980. Noncitrus Fruits and Nuts Annual Summary, Jan. ESCS Crop Reporting Board.
- U.S. Dept. Comm. 1977. Fats and Oils Production, Consumption, and Stocks, Summary for 1976. Cur. Ind. Rep. M 20k(76-13). Dec. 15 p.
- U.S. Dept. Comm. 1978. Fats and Oils Production, Consumption, and Stocks, Summary for 1977. Cur. Ind. Rep. M 20k(77-13). Dec. 15 p.

- U.S. Water Resources Council. 1978. Agricultural Price Standards: Guideline 2. Oct. Wash., D.C.
- Upshaw, R. 1978. Personal Communication. Aug. 14. Texas Agric. Ext. Serv. Texas A&M. Gail, Tex.
- Vento, S. 1978. Personal Communication. Oct. 18. C. B. Dolge Co., Westport, Conn.
- Virginia. 1977. External Parasites of Poultry. Ext. Div., Virginia Polytechnic Institute and State Univ., Blacksburg, Va.
- Virginia. 1977a. Insect Control for Ornamentals, Gardens and the Home: Household Insect Pests, Publ. 415. Ext. Div., Virginia Polytechnic Institute and State Univ., Blacksburg, Va.
- Virginia. 1978. Natural Control Methods of Insects in Your Home and Garden, Publ. 482. Ext. Div., Virginia Polytechnic Institute and State Univ., Blacksburg, Va.
- Virginia. 1978a. 1978 Virginia Pest Management Guide, Chemical Control of Insects, Plant Diseases, Weeds. Ext. Div., Virginia Polytechnic Institute and State Univ., Blacksburg, Va.
- Wackermann, J. 1979. Personal Communication. Sept. 5. Los Angeles Chem. Co., South Gate, Calif.
- Wackermann, J. 1979a. Personal Communication. Dec. Los Angeles Chem. Co., South Gate, Calif.
- Walker, J. D., and R. R. Colwell. 1976. Measuring the Potential Activity of Hydrocarbon-Degrading Bacteria. Appl. Environ. Microbiol. 31(2):189-197.
- Walker, J. K., R. E. Frisbie, and G. A. Niles. 1978. A Changing Perspective: Heliothis in Short-Season Cottons in Texas. Bull. Entomol. Soc. Am. 24(3):385-391.
- Walker, J. K., and Parker. 1979. Impact of Loss of Arsenic Acid on Cotton Insect Management in Nueces and San Patricio Counties of Texas. Texas A&M. College Station, Tex. Unpubl. Rep.
- Walton, V. A. 1978. Personal Communication. Sept. 4. Anderson Clayton. Temple, Tex.
- Ward, J. M. 1963. Effect of Seed Cotton Moisture Content on Cotton Fiber Quality as Reflected by Certain Fiber Properties. Texas Agric. Exp. Stn. Prog. Rep. 2267.
- Washington. 1977. Chemical Insect Control Handbook. College of Agriculture, Coop. Ext. Serv., Wash. State Univ., Pullman, Wash.
- Washington. 1979. Fleas. College of Agriculture, College of Agriculture, Coop. Ext. Serv., Wash. State Univ., Pullman, Wash.
- Watkins, J. R. 1978. Personal Communication. Nov. 30. Caddo Mills, Tex.
- Webb, D. A. 1979. Personal Communication. Koppers Co., Pittsburgh, Pa.

- West Virginia. 1976. Pest Information Series 96: Fleas and Their Control. Center for Extension and Continuing Education, West Virginia Univ., Morgantown, W. Va.
- West Virginia. 1977. Pest Information Series 56: Swine. Center for Extension and Continuing Education. West Virginia Univ., Morgantown, W. Va.
- Wheeler, J. R., and R. F. Ford. 1974. Defoliation with Heat. Proc. Beltwide Cotton Prod. Res. Conf. Natl. Cotton Council, Memphis, Tenn. p. 57-60.
- White, L. W. 1980. Personal Communication. Mar. 24. Green Hill Yacht and Country Club, Salisbury, Md.
- Whiteley, E. L., C. A. Rinn, C. E. Bolton, and O. Smith. 1979. Narrow Row Cotton in the Central Blacklands. Texas Agric. Exp. Stn. MP-1407.
- Wilkes, L. H., B. J. Cochran, and D. I. Dudley. 1959. Harvesting Cotton with Mechanical Pickers and Strippers, College Station and Denton, 1958. Texas Agric. Exp. Stn. Prog. Rep. 2076.
- Wilson, W. C. 1978. Personal Communication. Univ. Fla., Gainesville, Fla.
- Winkler, L. E. 1978. Personal Communication. Sept. 27. Texas Agric. Ext. Serv. Texas A&M. Albany, Tex.
- Wisconsin. 1975. Poultry Farm Pest Control. College of Agricultural and Life Sciences, Division of Economics and Economic Development, Univ. of Wis., Madison, Wis.
- Wolfe, H. R., J. F. Armstrong, D. C. Staiff, and S. W. Comer. 1972. Exposure of Spraymen to Pesticides. Arch. Environ. Health 25:29-31.
- Wolfe, H. R., W. F. Durham, and J. F. Armstrong. 1967. Exposure of Workers to Pesticides. Arch. Environ. Health 14:622-633.
- Wood, J. 1979. Personal Communication. U.S. Dept. Agric., Plant Prot. and Quar. Prog., Hyattsville, Md.
- Woolson, E. A. 1969. The Chemistry and Toxicity of Arsenic in Soils. Ph.D. Dissertation. Univ. of Md. Diss. Abstr. Int. B. 1970. 31(1)120.
- Wright, H. S. 1970. Test Method for Determining the Viricidal Activity of Disinfectants Against Versicular stomatitis Virus. Appl. Microbiol. 19(1):92-95.
- Wuest, P. J. 1979. Personal Communication. May. Pa. State Univ., University Park, Pa.
- Yagi, J. 1979. Personal Communication. Jan. 25. FMC Corp., Fresno, Calif.
- Yoder, J. B., J. W. Sinder, and E. Mauser. 1950. Experience with Zinc Ethylene Bis-Dithiocarbamate as a Fungicide in Mushroom Cultivation. Mushroom Science-1. (May) Proc. First Intl. Conf. on Scientific Aspects of Mushroom Growing, Peterborough, Northamptonshire, England.
- Young, H. C., and J. C. Carroll. 1951. The Decomposition of Pentachlorophenol When Applied as a Residual Pre-emergence Herbicide. Agron. J. 43:504-507.

- Young, R. W. 1980. Personal Communication. Meadow Lake Golf Course, Enid, Okla.
- Zaninovich, A. V. 1979. Personal Communication. Oct. 2. Vincent B. Zaninovich & Sons, Inc., Delano, Calif.
- Zaninovich, G. A. 1979. Personal Communication. Oct. 20. Jasmine Vineyards, Delano, Calif.
- Zaninovich, J. G. 1979. Personal Communication. Nov. 16. Jack G. Zaninovich Farms, Porterville, Calif.
- Zaninovich, M. B. 1979. Personal Communication. Oct. 4. M. B. Zaninovich, Inc., Delano, Calif.
- Zaninovich, N. 1979. Personal Communication. Sept. 28. A & N Zaninovich, Delano, Calif.
- Zobell, C. E. 1950. Assimilation of Hydrocarbons by Microorganisms. Adv. Enzymol. 10:443-486.
- Zobell, C. E., C. W. Grant, and H. F. Haas. 1943. Marine Microorganisms Which Oxidize Petroleum Hydrocarbons. Bull. Am. Assoc. Pet. Geol. 27:1175-1193.
- Zontek, S. J. 1980. Personal Communication. Apr. 14. U.S.G.A. Green Section Far Hills, N.J.
- Zwick, R. W. 1979. Personal Communication. Oct. 15. Oregon State Univ., Corvallis, Oreg.